APPENDIX E

Preliminary Evaluation for Flood Mitigation at McKenna

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INTRODUCTION

The unincorporated community of McKenna is located in southern Pierce County, Washington along the Nisqually River (see Figure 1, attached). This community has a history of flooding problems, most notably; an event in February 1996 that inundated portions of more than 80 parcels within the community. The purpose of this Technical Information Memorandum 4 (TIM No. 4) is to perform a preliminary evaluation of flood mitigation alternatives based on currently available information. To fulfill the stated purpose, the following specific objectives were met:

- Obtain and review available information regarding the existing flooding conditions at McKenna including the currently effective Flood Insurance Study (FIS) and Flood Insurance Rate Maps (FIRM) from the Federal Emergency Management Agency (FEMA).
- Briefly review available hydrologic information for the Nisqually River (e.g., flood flow estimates, current operating procedures for upstream dams). A more-detailed evaluation of Nisqually River hydrology including recommendations for an updated hydrologic analysis is presented in TIM No. 3.
- Summarize existing hydraulic conditions pertaining to flooding at McKenna (e.g., mapped flood hazards, historically flooded regions, flow constraints, etc.)
- Define a planning objective, develop a list of potential flood mitigation measures, and perform a screening-level evaluation of those measures with respect to such considerations as technical, environmental/regulatory, and cost constraints.
- Based on the review of available data and the evaluation of flood mitigation measures, provide recommendations for additional studies and subsequent actions.

This TIM is being developed as part of Nisqually River Basin planning efforts for Pierce County Surface Water Management (County). Recommendations for further studies will be included as elements of the Nisqually River Basin Plan.

BACKGROUND AND EXISTING CONDITIONS

The community of McKenna is situated along the north bank of the Nisqually River at approximately River Mile (RM) 22. In this region, the Nisqually River forms the border between Pierce County to the north and Thurston County to the south. It is located approximately 2 miles east of Yelm, Washington and 5 miles south of Roy, Washington.

As an unincorporated community, McKenna has no administrative boundaries. For the purposes of this memorandum, the community of McKenna refers to the developed areas along the north bank of the Nisqually River beginning at the Tacoma Rail Mountain Division (TRMW) Railway and ending approximately 1.5 miles upstream. Figure 2 (attached) shows McKenna and vicinity.

Nisqually River Hydrology

The Nisqually River originates from the Nisqually Glacier on the south slope of Mount Rainier and flows approximately 78 miles, west-northwest, to the Nisqually Estuary, where it flows into South Puget Sound. The watershed covers an area of approximately 760 square miles. La Grande Canyon, at RM 40, divides the Nisqually River watershed into two distinct physiographic areas. Below the canyon, the watershed consists of low hills and prairie plains of glacial outwash. Above the canyon, volcanic rock and steeper mountainous terrain dominate the area. Major tributaries include Mineral Creek, Little Nisqually River, Mashel River, Ohop Creek, Tanwax Creek, and Muck Creek.

The following sections briefly describe Nisqually River hydrology as it pertains to McKenna. The first section addresses upstream flow controls (dams) influencing river flows at McKenna. The second section is an overview of historical stream flow data collected at a nearby stream gauge. The third section presents flood frequency data currently used by FEMA for floodplain mapping. A more detailed review of Nisqually River hydrology can be found in TIM No. 3.

Flow Controls and Channel Modifications

The Nisqually River is relatively undeveloped with the exception of two hydroelectric facilities: the Nisqually Hydroelectric Project, which includes two major dams (La Grande and Alder), and the Yelm Hydroelectric Project, which includes a small diversion dam. The locations of these dams and other known modifications to the Nisqually River are shown in Figure 3 (attached). The following sections describe the two hydroelectric projects in relation to flood flows at McKenna.

Nisqually Hydroelectric Project – The Nisqually Hydroelectric Project is owned by the City of Tacoma and operated by Tacoma's hydroelectric utility, Tacoma Power. Flows in the lower reaches of the Nisqually River are regulated in part by the Nisqually Hydroelectric Project, which is comprised of La Grande Dam at RM 42.4 and Alder Dam approximately 2 miles upstream at RM 44.2. The original La Grande Dam was built in 1912. This dam was replaced in 1945 and Alder Dam, and its associated reservoir, was added that same year.

La Grande Dam is 192 feet high and has an impoundment storage capacity of 2,700 acre-feet. River flow is diverted at the dam to the powerhouse located approximately 1.7 miles downstream. The diverted water re-enters the Nisqually River downstream of the powerhouse. Water is also released from the impoundment to the Nisqually River to maintain a continuous flow. Alder Dam is 285 feet high and has an impoundment storage capacity of 231,900 acre-feet (Alder Lake). The powerhouse is located at the base of the dam.

In addition to providing hydroelectric power, the Nisqually River Project provides recreational benefits. Alder Lake and its associated parks are used for fishing, camping, picnicking, swimming, water skiing, and boating. The impoundment behind La Grande Dam is not publicly accessible because of the steep topography.

The Nisqually Hydroelectric Project is operated under a license issued by the Federal Energy Regulatory Commission (FERC). The 40-year FERC license (No. 1862) was issued on March 7, 1997. This license contains articles pertaining to operational requirements, including minimum instream flows and reservoir water levels. There are no requirements for flood control or flood storage.

According to Tacoma Power – the operator of the dams – the dams do provide some incidental attenuation of flood flows; however, there are no flood control requirements for the Nisqually Hydroelectric Project. When possible and consistent with federal mandate, Tacoma Power voluntarily uses the available storage space to help reduce the downstream crest of the flood. However, Tacoma Power will do so only when these operations remain consistent with prudent operation of the project and the requirements of its federal license (personal communication with Todd Lloyd, Tacoma Power, October 2006).

Yelm Hydroelectric Project – The Centralia Diversion Dam is part of a 12 megawatt run-of-the-river hydroelectric project located at RM 26. The project is owned by City of Centralia Light Department and operated under a 40-year FERC license (No. 10703-001) issued on March 7, 1997. The diversion dam was constructed in 1930, expanded in 1955, and reconstructed in 1985. The dam is a low head structure that diverts water into a 9.1-mile canal that conveys water to a powerhouse downstream at RM 12.6.

There is no impoundment at the diversion dam, which is a concrete gravity dam with a structural height of 20 feet, but a hydraulic height of only 4 feet at low stages. During high stages the dam is almost completely submerged, with a difference between headwater and tailwater of less than 1 foot (Golder, 2003).

Historical Flow Records

The United States Geological Survey (USGS) has collected flow data at numerous stream gauges in the Nisqually River watershed (see Figure 4). The primary active gauges on the Nisqually River include:

- USGS Station No. 12082500 – Located upstream of Alder Dam near the community of National (RM 57.8).
- USGS Station No. 12086500 – Located downstream of La Grande Dam (RM 40.4).
- USGS Station No. 12089500 – Located near the community of McKenna (RM 21.8).

All of these are real-time stream gauging stations. Two additional real-time gauging stations are operated in the watershed: one on Mineral Creek (USGS Station No. 12083000) and one on the Contra Costa Diversion Canal (USGS Station No. 12089208). There are two active, non-real-time gauges operated on tributaries: USGS Station No. 12088000 on Ohop Creek and USGS Station No. 12087000 on the Mashel River. USGS also operates gauges at La Grande Dam (No. 12085500) and Alder Dam (No. 12085000), but these record only reservoir stage, not flow. Figure 5 shows a map and schematic of the USGS stream gauging system in the Nisqually River Watershed.

Peak annual flow data for each of the three primary gauge stations on the Nisqually River are plotted in Figure 6.

Peak flows have been collected at National (USGS Station No. 12082500) for over 64 years beginning in 1943. Additional data are available from a gauge that was installed at Alder (USGS Station No. 12084000), approximately 10 miles downstream, recorded from 1932 to 1944. Peak discharges at the Alder gauge were 72% and 76% higher than the National gauge for the 2 years with overlapping records: 1943 and 1944, respectively.

Peak flow data have been collected at La Grande (USGS Station No. 12086500) since 1907. Four years of data were collected before the first La Grande Dam was built in 1912. Another 12 years of data were collected from 1920 to 1931. Flow records began again in 1945 (after the new La Grande and Alder Dams had been built) and has continued to present. A total of 78 years of peak flow data are available at this gauge; 62 of those years came after La Grande and Alder Dams were completed.

Flow measurement at the McKenna gauge began in 1947 and has continued to present. However, flow data were not collected between 1968 and 1977. During the 1968-77 data gap there was an active USGS gauge upstream of McKenna near RM 33 (USGS Station No. 12088400); data are available at this location from 1942 to 1979. Gauge data at No. 12088400 could be used to augment the data at the McKenna gauge to create a larger or more continuous period of record.

A more detailed discussion of USGS flow records is included in TIM No. 3.

Magnitude and Frequency of Flood Flows

The Federal Emergency Management Agency published a Flood Insurance Study of unincorporated Pierce County in 1987 (FEMA, 1987). A detailed hydrologic analysis of the Nisqually River was conducted for the FIS using the USGS stream flow data available at that time. Peak discharges were estimated at several locations along the River (see Table C-1).

Table E-1. Flood Frequency for the Nisqually River (FEMA, 1987)					
Location on Nisqually River	Drainage Area (sq.mi.)	Peak Discharges (cfs)			
		10-Year	50-Year	100-Year	500-Year
At Mouth[1]	711	21,500	29,000	33,000	45,000
Upstream of Horn Creek[1,2]	488	21,000	28,000	32,000	44,000
Upstream of Tanwax Creek[1]	446	20,500	27,000	31,000	43,000
At Skate Creek Road	79	6,250	9,080	10,400	13,600
At Mt. Rainier National Park	66	5,400	7,910	9,040	11,900

1. Discharges reflect conditions downstream of the La Grande and Alder Dams.

2. The community of McKenna is located downstream of the Horn Creek confluence. There is no significant tributary flow input between Horn Creek and McKenna. Therefore, these flows numbers plus an estimate of Horn Creek flows are essentially equal to flows at McKenna.

The FIS does not specify which USGS stream gauges were used in the hydrologic analysis, nor does it specify the period of historical records used. However, the latest year that could have been included is 1987. At a minimum, there are an additional 20 years of flow records that have been collected since the publication of the FIS. Included in these recent flow records is the largest peak discharge on record for the Nisqually River, which occurred in 1996, when there was an estimated flood flow of 50,000 cubic feet per second (cfs) at the McKenna gauge (No. 12089500). Not only is this peak discharge substantially larger than the 100-year discharge listed in Table C-1, but exceeds even the 500-year discharge. A preliminary analysis of flow data at McKenna indicates that the inclusion of additional recent flow records would increase flood flow frequency estimates, but perhaps by only about 10 percent. A more detailed discussion of hydrologic data and analyses is provided in TIM No. 3.

Flooding Conditions near McKenna

The Pierce County Natural Hazard Mitigation Plan (2005) describes flooding along the Nisqually River as "extremely variable in terms of frequency, severity, and extent." According to the FIS, floods occur from October through March as a result of rain storms, which are often augmented by snowmelt. In addition, the FIS describes flood damage along the Nisqually River as "generally limited to the community of McKenna...and to the Nisqually Delta" (FEMA, 1987). The following sections describe the flooding conditions at McKenna.

Regulated Flood Hazard Zones

As a participant in the National Flood Insurance Program (NFIP), Pierce County has adopted the Flood Insurance Rate Maps published by FEMA, which show flood hazard zones for the Nisqually River. To establish the flood hazard zones, FEMA conducted a detailed study of the lower portion of the river (below the confluence with Ohop Creek) as part of the FIS (FEMA, 1987). A recent update of floodplain mapping was completed by FEMA for several major flooding sources in Pierce County. However, the Nisqually River was not included in these updates.

A hydraulic model of the Nisqually River was developed for the FIS. Steady-state hydraulic simulations using the estimated 10-, 50-, and 100-, and 500-year peak discharges were run to calculate hydraulic profiles (peak water surface elevations) as shown in Figure 7. Based on the results of the hydraulic analysis, three types of flood hazard are mapped for the McKenna area: Zone A5/A6, Zone B, and the floodway. Copies of the FIRM are shown in Figure 8, and each flood hazard designation is described in more detail in the following paragraphs.

1. **Numbered A Zone (Zone A5 and Zone A6) –** This was delineated based on the areas inundated by the estimated water surface elevations for the 100-year flood (i.e., the 1 percent annual chance flood). The 100-year flood is referred to as the base flood, and the 100-year water surface elevations are referred to as base flood elevations. The numbers on numbered "A" zones are flood hazard factors, where "Zone A6" has a higher hazard than "Zone A5." On more recent FIRM panels, Zone B flood hazard areas that are associated with riverine flooding are referred to as "Shaded Zone X." The area inundated by the base flood is regulated by FEMA as the Special Flood Hazard Area (SFHA).

2. **Zone B –** This zone is the area between the 100-year inundation area and the 500-year inundation area. On more recent FIRM panels, Zone B flood hazard areas that are associated with riverine flooding are referred to as "Shaded Zone X."

3. **Floodway –** The "regulatory floodway" is defined as the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height. That designated height is 1 foot for FEMA mapping.

Pierce County Code contains more-stringent flood hazard regulations than what is required by the NFIP. The County has refined the definition of a floodway to include other high-hazard areas. The following are two such areas, which are regulated by Pierce County as floodways:

1. Areas of deep and/or fast flowing water (DFF): These areas are defined by specific combinations of depth-velocity criteria. The DFF floodway has not yet been mapped for the McKenna area.
2. Channel Migration Zone (CMZ): These are areas along a watercourse over which the river can move episodically over time.

Pierce County flood regulations limit development within the floodway and the flood fringe, which is the portion of the SFHA that is not considered a floodway. In general, new structures or structures with substantial improvements are not allowed in the floodway, and new structures or structures with substantial improvements within the flood fringe must be elevated to a minimum of 2 feet above the base flood elevation. For specific regulations refer to Pierce County Code (18E.70.040, Flood Hazard Area Standards). Pierce County flood hazards for the McKenna area are mapped in Figure 9.

Flood Warning and Emergency Response

Flood warning information is provided by the National Weather Service (NWS), which issues flood advisories, watches, and warnings based on flood forecasts. The NWS River Forecasting System collects data on current hydrologic conditions and combines them with meteorological forecasts to produce river stage forecasts. Flood warnings are disseminated to the public via radio, television, and local emergency agencies.

The gauging station at McKenna is part of the NWS forecasting system. The NWS issues a flood warning for the Nisqually River when its forecast model indicates the river will reach a stage of 12 feet or higher at the McKenna gauge. The NWS has defined four general stages of flooding for flood warning purposes. For McKenna these stages are:

1. Action Stage = 9 feet: agencies need to take steps toward mitigation and prepare for possible flooding.
2. Flood Stage = 12 feet: flooding begins to cause damage.
3. Moderate Flooding = 13 feet: transfer of property to higher elevations and some evacuation might be required.
4. Major Flooding = 14 feet: extensive inundation and property damage; usually requires evacuation and road closures.

The NWS has defined specific flood impacts for various stages of the Nisqually River at the McKenna gauge as provided in Table C-2.

Table E-2. Flood Impacts for Various Stages at the USGS McKenna Gauge (NWS, 2007)

Flood Stage	Description of Flooding Conditions
16 feet	The Nisqually River will cause severe near record flooding from La Grande downstream through McKenna to the mouth. Deep and swift flood waters will inundate roads...farms...and residential areas...including the nursing home in McKenna. Erosion will likely cause severe damage. Flooding will occur all along the river including headwaters...tributaries...and other streams within and near the Nisqually River Basin.
14 feet	The Nisqually River will cause major flooding from La Grande downstream through McKenna to the mouth. Deep and swift waters will flood roads...farms...and residential areas...including the nursing home in McKenna. Erosion may cause severe damage. Flooding will occur all along the river including headwaters...tributaries...and other streams within and near the Nisqually River Basin.
13 feet	The Nisqually River will flood from La Grande downstream through McKenna to the mouth. Swift waters will flood roads...farms...and some residential areas including the nursing home in McKenna. Erosion will likely damage properties along river banks.

Table E-2. Flood Impacts for Various Stages at the USGS McKenna Gauge (NWS, 2007)	
Flood Stage	Description of Flooding Conditions
12 feet	The Nisqually River will flood from La Grande downstream through McKenna to the mouth. Flood waters will flow over some roads and through farms and residential areas. Erosion may damage some properties. High tidal levels on Puget Sound will cause flooding along the lower reaches...threatening homes along Riverside Riverside Drive...Connine Street and Conine Avenue.
10 feet	The Nisqually River will spill over its banks between La Grande and McKenna. High tide levels on Puget Sound may cause the river to spill over its banks near the mouth.

Pierce County – The Pierce County Department of Emergency Management (DEM) is responsible for preparing for disasters and emergencies. The Emergency Management Division within the DEM provides guidance to all County agencies through the Comprehensive Emergency Management Plan.

In the event of a flood notification on the Nisqually River, the Emergency Management Division activates the Emergency Operation Center to coordinate emergency response (e.g., sheriff and fire departments) and alert residents of impending floods on specific rivers and streams within the county. Flood notifications for the Nisqually River can be received as either a flood advisory/watch/warning from the NWS, or as a notification from Tacoma Public Utilities informing of high releases from dams at the Nisqually Hydroelectric Project.

Flood alert information is provided on the County's Flood Information Line, and is posted on the County's Flood Event Information Web Page. When necessary, the Emergency Operation Center will implement the "Intelecast," which functions as a "reverse 9-1-1" calling system that issues warnings to land-lines within a specific area. In the event of a flood warning, the Intelecast system can be implemented to send telephone messages from DEM to residences that are considered at-risk based on current flood mapping.

Thurston County – Flood warning information issued by the NWS River Forecasting System for the Nisqually River is also disseminated by the Thurston County Emergency Operations Center through newspapers, radio, television, and internet. This Emergency Operations Center will supplement or amplify the information issued by the NWS when there is additional knowledge of local flooding effects, information from dam operators, or observations from field personnel (Thurston County, 1998). The Thurston County Emergency Operations Center will also provide information to fire and law enforcement agencies, Thurston County Departments, the American Red Cross, and volunteer organizations and make recommendations for community level warnings, evacuation, and transportation and shelter needs.

If forecasted flooding conditions necessitate evacuations or personal protective actions, then the Thurston County Emergency Operations Center will activate the "Tel-A-lert" system, which is a "reverse 9-1-1" system that functions similarly to Pierce County's Intelecast System. The

following are thresholds specified in the Thurston County Comprehensive Emergency Management Plan for activating the Tel-A-lert system on the Nisqually River:

- Upstream of Centralia Diversion Dam: 6,000 cfs from La Grande Dam
- Nisqually Delta: 13,000 cfs at McKenna
- Nisqually, at the community of Nisqually Pines: 19,000 cfs at McKenna

Historical Flooding Events at McKenna

The largest flood on record at McKenna (USGS Station No. 12089500) is an event in February 1996, during which the river crested at 17.1 feet at an estimated peak discharge of approximately 50,000 cfs[1]. Other large flooding events of record include January 1965 (25,700 cfs cresting at 13.0 feet), November 1995 (cresting at 12.5 feet), December 1980 (21,100 cfs cresting at 12.4 feet), and December 1955 (20,200 cfs cresting at 12.4 feet).

The FIS discusses large floods on the Nisqually River, including two floods that occurred during the gap in gauge records at USGS Station No. 12089500. Peak discharges of 30,700 cfs in December 1975 and 23,200 cfs in January 1974 were recorded at USGS Station No. 12088400, 10 miles upstream of McKenna (FEMA, 1987). Peak flood discharges at Station No. 12088400 have a strong correlation with peak flood discharges at Station No. 12089500 and were usually within about 10 percent of each other for peak flood discharges during overlapping years of record. Assuming the peak flood discharges that occurred at USGS Station No. 12088400 in December 1975 and January 1974 were similar in magnitude to the peak flood discharges that occurred at McKenna, flood stages can be estimated by examining the stage-discharge relationship at the McKenna gauge (USGS Station No. 12089500). Figure 10 is a plot of stage versus discharge for the peak annual discharges recorded at USGS Station No. 12089500. Based on Figure 10, the peak flood discharges occurring in December 1975 (30,700 cfs) and January 1974 (23,200 cfs) would have produced flood stages of approximately 14.0 feet and 12.5 feet, respectively.

Flooding in Pierce County in the mid-1990s led to presidentially declared disasters in November/December 1995, February 1996, December 1996/February 1997, and March 1997 (DEM, 2007).

February 1996 Flood – The most severe flood event to impact the community of McKenna occurred in February 1996 when the flood stage reached 17.1 feet, over 5 feet above flood stage. Figure 11 shows the estimated area inundated by the February 1996 event based on observations of flood levels (Dixon, 2006a). Although damage to the McKenna area was considerable, a specific estimate of damages has not been totaled.

[1] Discharge for the February 1996 event was estimated by extrapolation because the recorded stage exceeded the available rating curve.

According to an analysis by Dennis Dixon at Pierce County Surface Water Management, 79 parcels were inundated during that event (Dixon, 2006b). Following the flooding event, Pierce County purchased 25 of these parcels at a cost of approximately $2.5 million. These parcels are now managed by the McKenna Water District. Roughly 60 of the 1996-flooded parcels, including a nursing home, remain under private ownership. The taxable value of the remaining parcels is on the order of $6 million (Dixon, 2006b).

PRELIMINARY EVALUATION OF FLOOD MITIGATION

This section provides a preliminary look at flood mitigation planning for the McKenna area. A planning objective is stated Section 3.1. Section 3.2 established basic planning criteria and discusses some of the important planning constraints. A range of potential flood mitigation measures is presented in Section 3.3; each measure is evaluated with respect to the planning criteria and constraints. This section is followed by recommendations in Section 4.

Planning Objective

Based on available information, Pierce County Surface Water Management has identified flooding at McKenna as a problem, and intends to develop a flood mitigation plan and a potential project to address the problem. The specific planning objective is:

> *To reduce the flood risk and damages to the greatest extent possible within the area inundated by the base flood (100-year) event along the north bank of the Nisqually River between the TRMW Railway Bridge and a point approximately 1.5 miles upstream. Flood risk refers to both the risk of damage to property and the risk to human safety.*

A preliminary evaluation of flood mitigation measures was completed based on this objective as presented in Section 3.3. It is important to note that such an evaluation is contingent upon the delineation of the 100-year flood inundation area. Currently, the best available floodplain information is based on the FIS completed by FEMA in 1987. However, given the substantial amount of information that has been collected since that study, an updated study is warranted. Mitigation measures not screened out by this preliminary analysis should be re-evaluated upon the completion of updated hydrologic and hydraulic analyses.

Evaluation Criteria and Planning Constraints

Two Federal sources of flood mitigation funding are the U.S. Army Corps of Engineers (USACE) and the Federal Emergency Management Agency (FEMA).

USACE follows a six step process for civil works projects. Step 2 requires that studies are conducted according to the Water Resources Council's Principles and Guidelines (WRC, 1983). The Water Resources Council was a group of experts convened by the United States government, and tasked with the development of a document to guide the formulation and

evaluation of studies for major Federal water resources development agencies. According to these principles and guidelines, evaluation criteria are as follows:

- **Completeness** is the extent to which a project provides all of the elements necessary to ensure the realization of the planned effects. It provides an indication of the degree to which the results are dependent upon the actions of others.
- **Effectiveness** is the extent to which an alternative plan alleviates the specified problems and achieves the specified opportunities.
- **Efficiency** is a measure of the cost effectiveness of the project expressed in terms of the net benefits.
- **Acceptability** is the workability and viability of the alternative plan with respect to acceptance by state and local entities and the public and compatibility with existing laws, regulations, and public policies.

FEMA provides recommendations for mitigation planning in a how-to guide for communities (FEMA, 2003). In this guide FEMA describes seven evaluation criteria:

- **Social:** The public must support the overall implementation strategy and specific mitigation actions. Therefore, the projects will have to be evaluated in terms of community acceptance.
- **Technical:** It is important to determine if the proposed action is technically feasible, will help to reduce losses in the long term, and has minimal secondary impacts.
- **Administrative:** Under this part of the evaluation criteria, you will examine the anticipated staffing, funding, and maintenance requirements for the mitigation action to determine if the jurisdiction has the personnel and administrative capabilities necessary to implement the action or whether outside help will be necessary.
- **Political:** Understanding how your current community and state political leadership feels about issues related to the environment, economic development, safety, and emergency management will provide valuable insight into the level of political support you will have for mitigation activities and programs.
- **Legal:** Without the appropriate legal authority, the action cannot lawfully be undertaken. When considering this criterion, you will determine whether your jurisdiction has the legal authority at the state, tribal, or local level to implement the action, or whether the jurisdiction must pass new laws or regulations.
- **Economic:** Cost-effective mitigation actions that can be funded in current or upcoming budget cycles are much more likely to be implemented than mitigation actions requiring general obligation bonds or other instruments that would incur long-term debt to a community.
- **Environmental:** Impact on the environment is an important consideration because of public desire for sustainable and environmentally healthy communities and the many statutory considerations, such as the National Environmental Policy Act (NEPA), to keep in mind when using federal funds.

For the purposes of this memorandum, the two sets of evaluation criteria will be merged as follows:

USACE Criteria:	Corresponding FEMA Criteria:
Completeness	Not Applicable
Effectiveness	Technical
Efficiency	Administrative, Economic
Acceptability	Social, Political, Legal, Environmental

When evaluating proposed flood mitigation measures, it is important to consider any constraints that may limit the feasibility of a project. These constraints could be technical, environmental, economic, legal, or political. The following are some important constraints that must be considered when evaluating flood mitigation project alternatives on the Nisqually River at McKenna:

- **Fish Habitat –** The Nisqually River provides valuable habitat for fish, and is utilized extensively by multiple salmon species for spawning, rearing, and migration. The selected flood mitigation project must minimize impacts to the fish habitat.
- **Thurston County –** The Nisqually River forms the boundary between Pierce and Thurston Counties. The selected flood mitigation project on the Pierce County side of the river (along the north bank) should minimize adverse impacts to flooding conditions on the Thurston County side of the river.
- **Permitting –** A structural flood control project could impact riparian and/or wetland habitat. Such impacts could make permitting difficult and costly. The selected flood mitigation project should minimize impacts to riparian and wetland habitat.
- **Federally Licensed Dams –** Each of the dams on the Nisqually River are operated under FERC licenses, and are therefore outside of the County's jurisdiction. The selected flood mitigation project should not rely on changes to the operations of any of these dams because it is likely to be met with strong resistance.

Potential Flood Mitigation Measures

A wide range of flood mitigation measures were considered as part of this preliminary study. The following sections briefly describe eight measures that were identified as having potential to mitigate flooding at McKenna. Each measure was evaluated by listing issues and considerations related to the criteria and constraints described in the previous section. Recommendations for the formulation of alternatives based on these measures are made in Section 4. In addition, Section 4 makes recommendations for subsequent actions and additional studies.

Measure No. 1: No Action

A *No Action* measure would not provide any specific mitigation for flooding conditions in the community of McKenna. No actions would be taken to protect property or prevent loss of life beyond the mitigation programs that currently exist (see Sections 2.2.1 and 2.2.3).

Residents and structures would be allowed to remain in flood hazard areas: either the floodway or the flood fringe. Pierce County Code currently prohibits development or substantial modifications to existing structures in the floodway, and requires new structures or substantially modified existing structures elevated such that the lowest floor is 2 feet above the base flood elevation (18E.70.040[B] and 18E.70.040[C] 6[a]). These regulations are intended to minimize future flood risk, but will not necessarily reduce existing flood risk.

The current flood warning system for the Nisqually River is based on the NWS River Forecasting System and notification of releases by Tacoma Public Utilities from Alder and La Grande Dams. Emergency response for flooding along the Nisqually River is coordinated by the Emergency Operations Centers for Thurston and Pierce Counties. Both of these centers have "reverse 9-1-1" telephone warning systems.

A true "no action" alternative does not include any recommendations for additional studies. As such, current flood mitigation efforts (floodplain regulations and flood warning/emergency response) would rely on existing information. However, it is possible that updated flood hazard mapping will be conducted in conjunction with map modernization efforts continually conducted by FEMA.

Measure No. 1 is compared against planning criteria (WRC, 1983) in Table C-3.

Table E-3. Evaluation of Measure No. 1 – No Action

Criterion	Considerations
Completeness	• This measure does not reduce flood risk and, therefore, does not achieve the stated objective. • Current flood hazard regulations could cause some structures to be elevated over the long term; however, this reduction in flood risk is entirely dependent upon outside actions.
Effectiveness	• This measure provides no additional flood protection. • Current flood hazard regulations could cause some structures to be elevated over the long term; however, this would only be required when substantial improvements are made.
Efficiency	• There are zero costs to implement this action; however, some associated costs could be attributed to future flood damages, or to the insurance premiums that will be required for land owners in the floodplain. • There are zero benefits associated with this action.

Table E-3. Evaluation of Measure No. 1 – No Action	
Criterion	Considerations
Acceptability	• Flood mitigation is a current and relevant concern to those land owners impacted by recent flood events. This measure would do nothing to help those owners. • Land owners paying insurance premiums would prefer to pay less, or not have to pay at all. This measure would do nothing to help those owners. • Allowing future flooding might be politically scrutinized. • There are no negative environmental impacts associated with this measure. • There are no environmental benefits associated with this measure. • This measure would not affect fish habitat or any other riparian or wetland habitats. • This measure would not produce any negative effects on Thurston County. • This measure does not require any changes to dam operations.

Measure No. 2: Flood Warning and Emergency Response

Improved *Flood Warning and Emergency Response* is a flood hazard mitigation measure recommended in the Pierce County Natural Hazard Mitigation Plan (Pierce County, 2004). The current system, as described in Section 2.2.2, is based on flood warnings issued from either the NWS River Forecasting System or notifications issued by Tacoma Public Utilities when releases will exceed certain thresholds. When a warning is issued, Pierce County Emergency Operations Center notifies the appropriate emergency management officials, and in extreme cases activates the Intelecast reverse 9-1-1 calling system. In addition, flood alert information is provided on the County's Flood Information Line and is posted on the County's Flood Event Information Web Page.

A more detailed study of the existing flood warning systems and emergency response plans should be conducted to assess the adequacy of the systems and identify specific methods to improve them. Based on preliminary research, the following is a list of improvements that should be considered:

1. Develop a McKenna-specific emergency response plan that provides clear actions and priorities for residents, employees, and emergency personnel. Such a response plan should include an element for public education to help increase awareness and preparedness in the community.
2. The NWS River Forecasting system could be improved by linking real-time river stage forecasting to flood hazard mapping, which could be made available on-line through the County's flood information web-page. Such a system could provide up-to-date information showing what areas are forecasted to flood, and could provide guidance to citizens and emergency personnel as to what areas need to take action.

3. Improve the dissemination of flood warnings. For example, a siren could be installed in McKenna to alert residents. Another option could be to augment the existing reverse 9-1-1 calling system by adding cellular telephones.
4. Improved warning time and accurate flood hazard mapping information could allow for additional emergency actions to be taken to reduce damages and improve safety. For example, residents could be allowed time to remove valuable property (e.g., automobiles). Given adequate warning time, authorized personnel can shut off and secure utilities such as gas and electricity.
5. Flood fighting methods could be integrated into the response plan (e.g., erecting a temporary flood barrier, sandbagging, etc.).
6. Improved integration of Alder and La Grande Dam data with flood warning forecasts.

The flood warning system would likely remain based on the existing NWS system; however, the system might need some enhancements to ensure appropriate communication and provide adequate warning time. Several elements of the flood warning and emergency response measure require knowledge of flood hazard zones. Updated hydraulic modeling of the Nisqually River channel and floodplain should be conducted to provide accurate mapping of flood hazard areas before these improvements are implemented.

Measure No. 2 is compared against planning criteria (WRC, 1983) in Table C-4.

Table E-4. Evaluation of Measure No. 2 – Flood Warning and Emergency Response

Criterion	Considerations
Completeness	• This measure relies heavily on the participation of residents and emergency personnel. • Flood warning and emergency response requires coordination between several entities. • There is a large amount of uncertainty involved in the implementation of a flood warning and emergency response plan. • This measure can be easily combined with other measures to provide a more complete mitigation project. • Gauges have a potential for failure during flooding events. • Many components of a flood warning system rely on electricity, which could be lost during major storm events.

Table E-4. Evaluation of Measure No. 2 – Flood Warning and Emergency Response	
Criterion	Considerations
Effectiveness	• A well-organized flood warning and emergency response system can be highly effective in reducing the risk to public safety. • Flood warning and emergency response is highly limited in terms of reducing property damages and associated economic losses. • Flood warning systems can be reliable in terms of warning residents, but will do little to prevent flooding damage and associated economic losses. • An organized emergency response plan can be highly effective. • Adequate warning time can provide time to implement numerous emergency actions. • Emergency response activities are limited by warning time. • Flood warning times are limited by technical constraints. • Temporary protection such as a flood barrier could be difficult to implement due to the required length and height.
Efficiency	• Much of the funding for emergency services is already in place. • There are considerable long-term costs associated with operating a flood warning system; however, some of this funding has already been allocated. • A flooding warning system requires constant and indefinite monitoring and maintenance. • Emergency response requires a large number of staff and emergency workers. • Infrastructure and land impacts would be minimal. • Adequate flood warning could potentially allow time to remove transportable property. • Adequate flood warning could potentially allow time to protect valuable property. • Most aspects of this measure are likely to only be implemented occasionally (during predicted flooding events).
Acceptability	• Likely to have substantial community support. • Support and cooperation provided by several political entities. • There are likely to be few legal challenges. • Physical structures associated with this measure are likely to be temporary. • There are no negative environmental impacts associated with this measure. • There are no environmental benefits associated with this measure. • This measure would not affect fish habitat or any other riparian or wetland habitats. • This measure would not create adverse impacts in Thurston County. • This measure does not require any changes to dam operations.

Measure No. 3: Elevating Structures

Elevating structures would reduce the flood risk to those structures and the property contained within them. Residential or commercial structures would be elevated can be elevated a variety of ways, such as placing the structure on engineered fill, raising the structure onto stilts/pilings, or extending foundation walls.

Identification of at-risk structures would be based on flood hazard mapping, and the elevation to which structures would be elevated or flood-proofed would be based on estimated flood elevations. Therefore, it is important to obtain the most updated information available to delineate flood hazard areas and determine flood elevations. New hydrologic and hydraulic studies should be conducted before elevating structures. In addition, elevation certificates should be completed for all at-risk structures to estimate lowest floor elevations and lowest adjacent grade, as well as determine if a structure is pre- or post-FIRM.

Measure No. 3 is compared against planning criteria (WRC, 1983) in Table C-5.

Table E-5. Evaluation of Measure No. 3 – Elevating Structures

Criterion	Considerations
Completeness	• This measure is dependent on cooperation and participation of McKenna residents. • Some land owners may refuse to sell. • Flood proofing is currently prohibited by Pierce County regulations. • Elevating structures is not allowed in the floodway, including areas that may be identified as a DFF floodway. • Access to some buildings can be difficult.
Effectiveness	• Elevating structures reduces flood risks as property is susceptible to less frequent events. However, this risk is not reduced as much as it would be if the property were removed from the flood zone altogether. • Residents remain in the flood hazard area. While the risk to property damage may be reduced, the risk to human safety remains. • Elevating structures may not be feasible in areas with excessively deep flooding. • Properly designed elevated structures could be effective in protecting a structure from floodwaters to a specific flood event. • Uncertainty related to hydrologic models, debris and areas of DFF could potentially compromise retrofitted structures. • Emergency access would still not be available to the structures during a flood. • Elevation of existing structures poses minimal technical challenges.

Table E-5. Evaluation of Measure No. 3 – Elevating Structures	
Criterion	Considerations
Efficiency	• Elevating numerous structures above the Base Flood Elevation (BFE) would be costly, especially in deep flooding areas where the amount the structure may need to be elevated several feet. • Legal and administrative costs with implementing a building elevation program could be significant depending on whether or not the buildings are pre-FIRM or post-FIRM. • Placing structures on engineered fill could result in compensatory storage requirements. • Implementing a program that coordinates and helps to implement all steps of funding, design and construction of elevated structures could be administratively challenging.
Acceptability	• Reducing floodplain storage could reduce flood flow conveyance and affect the attenuation of flood flows; these could cause adverse impacts to other areas including portions of Thurston County. • Environmental impacts would be minimal; mostly associated with construction activities. • Political pressures could come from groups that would rather see residents completely relocated out of the floodplain. • Land owners might resist elevating their homes. • A publicly funded and/or mandatory program might engender a substantial amount of political opposition. • This measure could have some affect on riparian and wetland habitats depending on the extent of engineered fill required to elevate the structures. • This measure does not require any changes to dam operations.

Measure No. 4: Acquisition of Flood-Prone Properties

This measure would consist of a program to buy out flood-prone properties and convert the land to open space. This measure could also include relocation assistance, which could include creating/identifying open lots or opportunities for developing new lands outside of the 100-year floodplain, or assisting tenants with finding new rental properties.

Removing people and properties from the flood hazard area would virtually eliminate the risk of damage to residential property. Additionally, the risk to human safety would be considerably lowered during a flood event, which can be particularly important in areas with hazardous flood flow conditions (e.g., DFF floodways).

Under FEMA's acquisition eligibility criteria, the property to be acquired would "*contain an at-risk structure, including those that are damaged or destroyed due to an event. In some cases, undeveloped, at-risk land adjacent to an eligible property with existing structures may be eligible.*" Another important note from FEMA's acquisition eligibility is that "*the property will be acquired from a willing, voluntary seller.*" Purchasing homes from residents who have a

long-standing relationship with their property and town may be difficult. To help alleviate some of the difficulties of relocating, the County could consider measures to help assist residents.

Following the flooding event in 1996, Pierce County purchased 25 parcels in the McKenna area at a cost of approximately $2.5 million. Some parcels are now managed by the McKenna Water District as open space. Roughly 60 of the parcels that were flooded during that event (including a senior center) remain under private ownership, with a total taxable value estimated to be on the order of $6 million (Dixon, 2006).

Properties would be acquired through a coordinated buyout program. An important first step is to develop updated hydrologic and hydraulic modeling of the Nisqually River channel and floodplain to provide improved mapping of flood hazard areas and better estimates of flood elevations. Eligible properties would then need to be identified and prioritized for acquisition. Another important step would be to assess the likelihood of success through public outreach. One method would be to conduct a resident survey to evaluate the level of interest for participating in a buyout. Additionally, the County could conduct a series of public meetings to keep the public closely involved in the process.

Measure No. 4 is compared against planning criteria (WRC, 1983) in Table C-6.

Table E-6. Evaluation of Measure No. 4 – Acquisition of Flood-Prone Properties

Criterion	Considerations
Completeness	• This measure is dependent on cooperation and participation of McKenna residents. • Some land owners may refuse to sell.
Effectiveness	• Acquiring properties and removing residents from the floodplain is a highly effective method for reducing flood risk for people and property. • Removing structures and residents from the flood hazard area nearly eliminates flood risk.
Efficiency	• Land acquisition costs could be significant. • Substantial cost could be added if relocation assistance is provided. • Relocation of a large number of residents and businesses could require substantial costs because existing infrastructure would likely be abandoned and new infrastructure would need to be designed and constructed. • Coordination of a buyout program will include administrative costs.
Acceptability	• Some land owners might resist selling. • Some residents and local businesses might resist the drastic changes to the community and could pose legal opposition. • Relocation of residents could be met with opposition in a new location if existing residents do not want new development. • Relocation properties elsewhere would increase the local development footprint and associated impacts.

Table E-6. Evaluation of Measure No. 4 – Acquisition of Flood-Prone Properties	
Criterion	Considerations
	• Acquired properties could be designated as open space, which could reserve areas for flood conveyance and provide storage of floodwaters to help attenuate flows. • Open spaces provide opportunities for habitat restoration. • Open spaces provide opportunities for public education, outreach and recreation. • A publicly funded and/or mandatory program might engender a substantial amount of political opposition. • This measure would not create adverse impacts in Thurston County. • This measure does not require any changes to dam operations.

Measure No. 5: Structural Flood Control – Levees

All of the measures presented thus far are non-structural alternatives. One structural alternative to flood mitigation would be to construct a flood control barrier such as a levee. A levee is an engineered earthen berm constructed to confine flood flows to a principal conveyance channel, or more-specifically, to prevent floodwaters from inundating specific areas. Two basic levee configurations were considered:

1. **Perimeter (Ring) Levee –** This option would involve placing a levee around the perimeter of the structures that are to be protected. Constructing a levee in this way minimizes the area of the floodplain that must be removed from active flood storage. Examples are shown in Figure 13.

2. **Bank Levee –** This option would consist of constructing a levee on the north bank of the Nisqually River beginning at high ground approximately 3,000 feet upstream of Highway 507 and ending at the existing railroad tracks approximately 1,300 feet downstream of Highway 507 (see Figure 14). This would tie the levee into the upstream and downstream high points. If the levee increases flood elevations, then another levee may be required on the south bank.

A number of considerations would require further investigation and evaluation before pursuing this option, including:

- Updated hydrology would need to be completed for the Nisqually River, as well as updated hydraulic modeling for the McKenna reach.
- Hydraulic analysis would be required to examine the effects on upstream and downstream areas, as well as areas across the river along the south bank. If it is shown that adverse impacts are created by constructing the levee, a takings analysis would need to be completed. In addition, hydraulic mitigation (e.g., compensatory storage) would need to be included as a project element.
- Geotechnical investigations would need to be conducted.

- Long-term levee maintenance activities would be required. Routine monitoring and maintenance items may include settlement monitoring, erosion inspections after storm events, and vegetation maintenance.
- As part of long-term monitoring and inspections, additional construction may be required, including installation of cutoff walls if inspections show an increasing seepage exit gradient.

Measure No. 5 is compared against planning criteria (WRC, 1983) in Table C-7.

Table E-7. Evaluation of Measure No. 5 – Structural Flood Control-Levees	
Criterion	Considerations
Completeness	• Levees do not completely eliminate the flood risk, and often create a false sense of security. • Levees require long-term maintenance.
Effectiveness	• A properly designed, constructed, and maintained levee can provide reliable flood protection to its design level; however, uncertainties are still inherent in this type of flood protection. • Levees require continual maintenance to maintain the design level of flood protection. • A properly designed, well-built, and maintained levee can provide a reasonable level of flood protection. However, there is the residual risk associated with the potential failure of a levee. • The residual risk is rarely communicated to the public nor recognized. • By isolating the majority of homes in the McKenna area, but not all homes, structures excluded from the levee's protection would continue to be prone to flooding and not benefit from the project.
Efficiency	• Initial geotechnical investigations, design, and construction of levees may be costly. • Levees can be costly to design and construct, particularly around existing roads and infrastructure (e.g., the existing State Route 507 bridge). • There would be technical challenges with tying the levees in with each of the two bridges in the McKenna area. This could also increase design and construction costs. • Long-term levee maintenance activities would be required and could be costly. • Levees can be extended and raised; this, however, greatly depends on the original design and location of the levee. Raising and retrofitting levees can be a difficult and costly procedure. • A tall levee (e.g., more than 10 feet) would result in a significant levee footprint with a base width of 70 feet or more. • Property acquisition may be required to achieve the most beneficial levee alignment. • Environmental impacts could make the project difficult to permit, which can be costly. • A significant levee footprint in a riparian corridor could destroy habitat and require offsite mitigation.

Table E-7. Evaluation of Measure No. 5 – Structural Flood Control-Levees	
Criterion	Considerations
Acceptability	• A structural solution such as this can have negative impacts on riparian and wetland habitat. • Containing flows in the Nisqually River could reduce flood flow conveyance and create adverse impacts to flooding in other areas. For example, constraining on the right bank could possibly result in increased flooding on the left bank, which could potentially impact the Centralia Canal and State Route 507, or cause new areas of flooding in Thurston County. • Homes within the levee area will be required to build behind the levee (e.g., no riverside home development). • Political pressures could be applied from downstream communities who fear an increase in flooding severity and frequency as a result of the project. • Permitting, funding, and public approval are all difficult to obtain for structural flood control solutions, especially those that alter the landscape and require ongoing maintenance. • Legal opposition could occur from neighboring downstream communities, environmental groups, or homeowners who may be faced with having to sell their home to facilitate the project. • A perimeter levee or a berm levee on the right bank of the Nisqually will result in a change in the general appearance of the Town of McKenna. • Depending on the height of the levee, residents existing views may be blocked. • Levees can limit accessibility to homes and businesses, as well as limiting recreational access to the river by residents. • A levee could have a negative impact on community aesthetics. For example, a perimeter levee or a berm levee on the right bank of the Nisqually will result in a change in the general appearance of the Town of McKenna.

Measure No. 6: By-Pass Canal

The Centralia Canal flows along the south side of the Nisqually River. The canal is part of a run-of-the-river hydroelectric power project. Water is diverted at a small diversion dam approximately 4.4 miles upstream of McKenna; the diverted flow in the channel runs parallel to the river to a power plant approximately 9.1 miles downstream, where it is returned to the river.

As part of a preliminary identification of alternatives, this canal was examined for its potential to be expanded to divert flood flows and by-pass McKenna. An examination of historical flows in the canal indicates that flows are typically on the order of 600 to 800 cfs. Flood flows in the McKenna River are in excess of 30,000 cfs. Even if the capacity of the canal could be expanded to three or four times the typical flow, it would still convey less than 10 percent of the flood flow in the Nisqually River.

If the Centralia Canal was expanded and retrofitted to convey flood flows, it would require a substantial amount of work to the diversion structure and flow controls at the powerhouse. Furthermore, expanding the canal could require considerable alterations to existing bridge crossings. Before pursuing this measure, additional investigations would need to be conducted to determine the feasibility. Considerations that would require additional investigation include:

- Physical and operational constraints at the power plant downstream of McKenna at the terminus of the canal would need to be determined. If an increased diversion from the Nisqually River was physically able to be sent down the canal, the power plant would either need to be able to utilize the extra flow or bypass it through the existing plant to the Nisqually River without disrupting operations.
- Hydraulic analyses to determine capacity of the canal, including an investigation of the required diversion structure, and any flow constraints along the canal alignment (e.g., culverts).

Measure No. 6 is compared against planning criteria (WRC, 1983) in Table C-8.

Table E-8. Evaluation of Measure No. 6 – By-Pass Canal

Criterion	Considerations
Completeness	• This measure would require cooperation from other entities (e.g., Centralia Power and Light).
Effectiveness	• Numerous technical challenges such as channel capacity, culverts, diversion retrofit and power plant configuration and operations could be substantial. • It is highly unlikely that the canal could by-pass enough flood flow to be a stand-alone measure. However, the diversion alternative may be combined with one of the other alternatives discussed in this TIM. • Technical constraints such as debris constricting flow at culvert crossings or power plant operational problems could compromise the reliability of this measure.
Efficiency	• Costs associated with increasing the size or capacity of the canal could be substantial. • Costs associated with changes to the existing infrastructure could be substantial. • Costs associated with changes in hydroelectric operations could be substantial. • Centralia's project is under federal (FERC) license. The costs of license modifications and associated environmental review would be substantial.
Acceptability	• Federal licensing for the Nisqually Project is a costly and time consuming process. Changes to the objectives and/or operational requirements of the project could require extensive administrative action and would likely be met with strong opposition. • Coordination with the power plant owners and operators would be significant. • Changes to the existing hydroelectric facilities could effect power production. • Changes to existing infrastructure may be met with political opposition.

Table E-8. Evaluation of Measure No. 6 – By-Pass Canal	
Criterion	Considerations
	• The project likely would engender substantial opposition from the Nisqually Indian Tribe and all federal and state fisheries agencies. • Increasing flow into the canal results in substantial risk of canal failure and subsequent flooding of homes in Thurston County adjacent to the canal. • Utilizing existing facilities would minimize the environmental impacts of developing new areas.

Measure No. 7: Reservoir Operations

Dams are commonly used to control flood flows on river systems. Available storage behind a dam can be used to attenuate flood flows, thus reducing peak discharges, lowering flood stages, and delaying the time of the flood crest. Lower peak discharges and lower flood stages provide the benefits of decreased flood damages and reduce the risk of loss of life. Delaying the time to the flood crest provides more warning time for McKenna residents. The increased warning time provides additional benefits for reduction in loss of life and decreased damages.

Flows in the lower Nisqually River are affected by the dams of the Nisqually Hydroelectic Project. The storage capacity of Alder Lake (the reservoir behind Alder Dam) is approximately 231,000 acre-feet, which is vastly greater than the impoundment behind La Grande Dam (2,700 acre-feet). As such, Alder Dam has the most potential for regulating downstream flows.

An engineering analysis has not been made available, nor has one been performed for this memorandum to confirm or deny the adequacy of Alder Dam and Alder Lake for providing flood control. Such an analysis would not only evaluate the overall capacity of Alder Lake to attenuate flood flows, but also analyze the operations of Alder Dam with respect to the project's objectives and requirements of the current FERC license. Even if Alder Lake has inadequate storage to prevent downstream flooding, the possibility may exist to execute minimal operational changes that could result in lowered flood stages and decreased flood damage severity, as well as provide an increase in warning time for McKenna residents. This is not to imply that the dams are not currently operated in such a manner, but at this point, the effects of operations at the dams are unknown. Such a determination would require considerable technical analyses.

Changes in operations to a hydroelectric project will have associated costs. If Tacoma Power were to see a negative economic impact as a result of a change in operations for flood control purposes, Pierce County and relevant stakeholders would most likely have to offset the cost.

Measure No. 7 is compared against planning criteria (WRC, 1983) in Table C-9.

Table E-9. Evaluation of Measure No. 7 – Reservoir Operations	
Criterion	Considerations
Completeness	• The capacity of the reservoirs for flood control is not known at this point. It is likely that the dams do not control enough of the drainage area, and that the capacity of the reservoirs is not adequate to entirely mitigate flooding at McKenna. • This measure would rely on cooperation from other entities (Tacoma Power).
Effectiveness	• Control of flood flows using dams has a high degree of reliability; however, there is some risk of failure. Furthermore, there is potential for human error in dam operations. • Dams have an operable lifespan associated with the loss of storage due to sedimentation.
Efficiency	• Technical challenges related to hydrology and hydraulics as well as balancing existing dam operations with possible future flood control needs could be technically challenging. • Operating the dam to provide flood control could negatively impact power production. These losses would need to be offset. • Federal licensing for the Nisqually Project is a costly and time consuming process. Changes to the objectives and/or operational requirements of the dams could require extensive administrative action. • Potential impacts to Endangered Species Act (ESA)-listed fish species would require extensive administrative action.
Acceptability	• Changes in operations would be met with strong opposition from Tacoma Power and other affiliated agencies. • Operation of the Alder and La Grande Dams are regulated under a FERC license, which would be difficult to alter due to opposition from numerous contributing agencies. • Pursuing changes to the current FERC license could provoke legal opposition. • Altering the operating curve of the reservoir would negatively impact Tacoma's ability to meet its minimum flow obligations under its FERC license. These minimum flows provide secure habitat for two fish species (Fall Chinook and Steelhead) listed as "Threatened" under the ESA. • The project likely would engender substantial opposition from the Nisqually Indian Tribe and all federal and state fisheries agencies. • Operating the dam to provide flood control could negatively impact power production, and could ultimately affect power rates. Such changes would likely be met with strong opposition. • Dam operational changes could affect water levels and impact recreational activities on Alder Lake. Such changes would likely be met with strong opposition. • The impact to existing lands and infrastructure would be minimal.

Measure No. 8: Removal of Sand and Gravel from River Bed

This measure would consist of excavating sand and gravel, deepening the river to increase conveyance capacity. Removal of sand and gravel deposits is highly regulated by various resource agencies. Washington Department of Fish and Wildlife does not allow the County to

remove sediment unless it can clearly demonstrate that public facilities or the general public safety and welfare is at specific risk due to the buildup of the material. Even then, permitting and mitigation would still be required, at all jurisdictional levels, and there is no guarantee that such activity would be permitted. The current climate in doing such activities are a result of the listing of Chinook Salmon and Steelhead as threatened species under the Endangered Species Act. Past activities to remove gravel, which were quite common and typical in rivers in the County, has changed drastically since the listing.

If dredging were permitted, the increase in conveyance may result in a small reduction in flooding risks. High flows may still spill into the floodplain damaging structures. Also, without other measures (i.e. grade control structures or a means to reduce sediment inputs), deepening the river will be temporary. Silt and gravel will continue to aggrade until a state of equilibrium is reached. Therefore, this measure is continual and indefinite, resulting in high costs.

Additional data and analysis would need to be completed to determine:

- Upstream sediment inflow rates;
- Where sediment should be removed;
- River access to dredging locations; and,
- Disposal of dredged material.

If there is a beneficial use for the dredged material, this could offset project costs. If there is no beneficial use, however, sediment should be disposed of outside the floodplain so as not to decrease floodplain capacity. In this case, disposal could be costly.

Measure No. 8 is compared against planning criteria (WRC, 1983) in Table 10.

TABLE 10. Evaluation of Measure No. 8 – Removal of Sand and Gravel

Criterion	Considerations
Completeness	• Removal of sediment might increase channel capacity, but it is not likely that the channel capacity could be increased enough to completely eliminate flooding. • Dredging provides temporary increases in capacity. To maintain increased capacity, this measure would need to be continual and indefinite.
Effectiveness	• Immediately after excavation, channel capacity would be increase. As time passes, the increased capacity would be diminished as the channel aggrades.
Efficiency	• Would require long-term maintenance, continual sediment removal. • Dredging would be costly and provide temporary benefits.
Acceptability	• Removal of bed sediments will cause a dramatic disturbance to aquatic habitat. • The project likely would engender substantial opposition from the Nisqually Indian Tribe and all federal and state fisheries agencies. Opposition could result in legal challenges. • Suspension and downstream transport of sediment could impact downstream reaches. • If dredging was a historic practice, when there were fewer flooding impacts, some

	communities may support it. • There are no environmental benefits associated with this measure. • This measure would not create adverse impacts in Thurston County. • This measure does not require any changes to dam operations.

RECOMMENDATIONS

The preliminary evaluation of each flood mitigation measure presented in the previous section provides a number of considerations to use in formulating project alternatives. A measure could be viewed as a stand-alone alternative for a flood mitigation project, but would more likely be implemented in conjunction with other measures to create a project alternative that more completely achieves the flood mitigation objective. The following paragraphs summarize the preliminary evaluation and provide a general guideline for developing viable project alternatives.

Recommendations for Flood Mitigation

"No Action" is probably not a viable option because it does little to achieve the objective of flood mitigation. However, it is important to include a no-action alternative in flood mitigation planning because it provides a baseline for comparing costs and benefits (a "no action" alternative has no costs and no benefits).

Developing an improved flood warning and emergency response system specifically for the Nisqually River and the McKenna area would provide considerable benefits with regard to public safety, and may even allow some protection for property damages. The measure is highly adaptable and can be implemented in conjunction with any other measures. Furthermore, most improvements to the flood warning and emergency response system could be executed relatively quickly, and be in place well before other mitigation measures that may follow. Flood warning and emergency response measures are not likely to meet opposition; and although they require the cooperation of several other entities, many of the resources are already in place.

Acquisition of flood-prone properties is the most effective method for reducing flood risk because people and improved property would be completely removed from the flood hazard zone. Acquisition is not likely to meet opposition from outside entities such as Thurston County or the Nisqually Tribe; however, there could be some opposition from residents who do not want to sell or move.

Elevating is also a viable method of reducing flood risk, although it is somewhat less effective than property acquisition. Elevating structures becomes more costly as floodwaters become deeper and the elevation level increases. Furthermore, elevating structures is allowed only in the flood fringe; the DFF floodway needs to be mapped for McKenna to delineate those areas where elevating structures will be allowed. As such, elevating structures is not likely to be a stand-alone alternative for flood mitigation. However, elevating structures could be used in

conjunction with property acquisition, which may provide a more complete and cost-effective alternative.

A structural alternative such as a levee is an effective means for providing flood protection. However, there is residual risk for areas protected by a levee because there is always some risk of levee failure. The greatest disadvantages to constructing a levee are the potential negative impacts to riparian/wetland habitat and the potential adverse impacts to other areas caused by the reduction in floodplain storage. These impacts would likely require mitigation offsets (e.g., offsite wetland restoration and compensatory storage), which could be costly and difficult to permit. Furthermore, these negative impacts will likely engender opposition from outside entities such as Thurston County and the Nisqually Tribe. Construction of a levee around the existing State Route 507 bridge could also be costly.

An alternative that includes mitigation measures involving one or more of the existing dams on the Nisqually River will likely be difficult to implement. Centralia Canal is not likely to provide enough flow-carrying capacity to significantly reduce flood flows, even if it was implemented in conjunction with other measures. Even if sufficient flood storage could be made available behind Alder Dam, any changes to dam operations will likely be met with strong opposition from outside entities such as Tacoma Power and the Nisqually Tribe. Furthermore, changes to the FERC licenses currently in effect for these dams would be time consuming, costly, and legally challenging.

In summary, flood mitigation project alternatives should include improvements for flood warning and emergency response, as well as some combination of property acquisition and elevating structures. Formulated alternatives should then be analyzed as part of a complete feasibility study including a benefit-cost analysis. Accordingly, the following section discusses recommendations for further studies and subsequent actions by the County, which will be included as elements of the Nisqually River Basin Plan. If the County decides to pursue flood mitigation project alternatives involving levees or changes to dam operations, then the Basin Plan could be amended to include additional relevant studies (e.g., geotechnical investigations, reservoir operations study, negotiations with Tacoma Power).

Recommendations for Further Studies and Actions

The following sections are specific recommendations for further studies and actions to be included as elements in the Nisqually River Basin Plan. These recommendations are based on the findings of the preliminary evaluation of flood mitigation measures presented in Section 3 and summarized in Section 4.1.

Perform Alternatives Analysis and Initiate Community and Stakeholder Involvement

An analysis of complete flood mitigation alternatives should be performed to identify a preferred alternative. The analysis is dependent on an updated hydrologic study (see recommendation in

Section 4.2.2), and revised flood hazard mapping (see recommendation in Section 4.2.3), as well as the determination of flood-prone structures (see recommendation in Section 4.2.4). Once these data have been collected project alternatives can be compared and evaluated. A benefit-cost analysis (BCA) should be performed in accordance with FEMA guidelines for application for disaster mitigation. FEMA provides a suite of software to assist with BCA analyses called the Mitigation BCA Toolkit. Additional analyses will need to be performed including estimation of potential flood losses, as well as estimation of costs associated with project implementation. Benefit-cost ratios should be developed for each project alternative including a "no action" alternative. Based on the benefit-cost comparison, a preferred alternative should be selected.

Community and stakeholder involvement is crucial to the success of a flood mitigation project, and should be initiated during early planning stages. Involving residents throughout the planning process maintains active communication, provides an understanding of the needs of the community, and garners support for the proposed project. Similarly, involving relevant stakeholders in the planning process facilitates interagency cooperation, and helps to develop multi-objective planning.

The County should conduct a series of community workshops to provide continual updates regarding the planning status. Workshops could be used to:

- Present the results of the preliminary evaluation of flood mitigation measures and discuss the upcoming planning process.
- Present the results of updated flood hazard mapping studies and discuss the implications.
- Discuss the formulation of project alternatives, their relative costs, benefits achieved, and the potential funding options.
- Assess the public sentiment, obtain feedback, and gauge interest for voluntary participation.
- Educate the public and relevant stakeholders about the existing flood hazards and increase awareness and preparedness.

An effective buyout program for property acquisition is dependent on residents' willingness to sell their property and relocate. The County should develop a questionnaire and conduct a survey of McKenna area residents to assess interest in a buyout program. The survey should be conducted after a community workshop has been held to explain how and why a buyout program is being considered. The questionnaire could be used to collect information that will be useful in coordinating a buyout program by helping to establish qualifications and prioritization criteria for determining who will be offered a buyout.

As necessary, the County should conduct meetings with relevant stakeholders and regulatory agencies to ensure cooperation and support. Three key stakeholders include Thurston County, the Nisqually Tribe, and the Pierce County Department of Emergency Management.

Update Nisqually River Hydrology

Existing flood flow frequency data for the Nisqually River is based on the 1987 FEMA study. Since this study, over 20 years of additional stream flow data have been collected. In addition, several large flooding events have occurred on the Nisqually River over the past 20 years including the 1996 flood, which was substantially larger than anything on record. An updated hydrologic study of the Nisqually River should be conducted to estimate a new set of flood flow frequency data.

There are various methods for conducting hydrologic analyses. Specific objectives should be defined for the study before determining the most appropriate methodology. The primary objective for use in flood mitigation is to develop new flood flow frequency data for the area of interest. Although the recommendation for updated hydrology was prompted by a need for updated data at McKenna, the scope of the analyses will encompass the lower portion Nisqually River (below La Grande Dam) because of the potential need for flood hazard mapping at other locations.

All relevant hydrologic analyses from previous studies should be collected and reviewed, particularly those studies completed by FEMA or USGS. In addition, historical stream flow data should be obtained from available gauge records (TIM No. 3 provides an assessment of available gauge data).

Relevant gauge data should be used to compile a continuous series of annual maximum instantaneous peak discharges at each of two primary gauge sites: 1) just downstream of La Grande Dam, and 2) near McKenna. Discharge-frequency analyses should be conducted in accordance with Bulletin 17B Guidelines (Interagency Advisory Committee, 1982), which could be performed using public domain software such as HEC-SSP or USGS PeakFQ. Bulletin 17B methodology is used to fit logarithms of annual peak discharges to a Pearson Type III distribution. This method includes options for improving the estimates using a regional skew coefficient, weighing stations and generalized skew to reflect relative gauge accuracy, and adjustments for outliers and gaps in records. Results are used to estimate the magnitude of flood discharges for various recurrence intervals (annual probabilities). Flood flow frequency data could be interpolated between the two primary gauge sites, weighted by the contributing drainage area.

Because flows downstream of La Grande Dam are influence by La Grande Dam and Alder Dam, a flood flow frequency analysis would be limited to gauge records subsequent to February 1945 (when the new La Grande Dam was completed). The analyses would assume that operations at the dams have remained constant and will not change in the future. Accounting for changes in dam operations would require more detailed hydrologic analyses, and would require additional data such as stage-storage information for the reservoirs, gate/spillway dimensions, operating rules, and mean daily flow data.

Update Flood Hazard Mapping

Once updated hydrology has been completed for the lower Nisqually River, flood hazard mapping can be updated. In addition to utilizing updated discharge-frequency data, an updated flood hazard mapping analysis can incorporate new topographic data and more-detailed hydraulic analyses. The study could focus on the reach of the Nisqually River adjacent to McKenna, or it could be expanded to include a much larger reach if updated flood mapping was needed in other areas.

A ground survey should be conducted to obtain cross-sections within the main channel of the Nisqually River along the length of the reach to be studied (including points along the channel bottom below the water surface). In addition, the locations and elevations of key hydraulic features (e.g., bridge crossings, grade breaks, roadway crowns) should be surveyed. These data can be combined with LiDAR[2] data covering the floodplain to create a single terrain model representing the existing channel and floodplain geometry. Integration and processing of the topographic data can be performed using geographic information systems (GIS).

Additional data for bridges or other structures that may affect river hydraulics need to be collected to estimate the dimensions of those structures. The most likely means for obtaining this information is requesting design drawings or as-built drawings from the owner of the structure. For example, the Washington Department of Transportation should have as-built drawings for the State Route 507 bridge in McKenna. In the absence of detailed data for a particular structure, field observations can be made to approximate relevant dimensions. In addition, a site visit should be conducted to observe channel and floodplain roughness, hydraulic structures, and historical high-water marks.

A hydraulic model of the Nisqually River study reach should be developed using a software package such as the HEC-RAS program developed by the Army Corps of Engineers. Topographic data and hydraulic structures data should be used to develop geometric input data. Cross-sections can be extracted from the GIS-based terrain model. Bridge and hydraulic structure dimensions can be taken from design/as-built drawings or from field observations.

Once the geometric input data have been developed, calibration can be performed based on historical water surface observations. For example, high water marks were observed during the flooding that occurred in the 1996 flood event. The estimated peak discharge from the 1996 event can be input into the model and the roughness parameters can be adjusted to achieve a water surface elevation approximately equal to the observed elevation.

[2] Light Detection and Ranging (LiDAR) is a method of collecting elevation data and developing terrain models. The County has recently obtained such data in cooperation with the Puget Sound LiDAR consortium, and it is assumed that these data will be made available in a format useful for flood analyses.

After the model is calibrated, flood flow frequency data can be input as peak discharges for use in a series of steady-state hydraulic simulations. The results will provide hydraulic profiles along the study reach, including flow velocities, depths, and water surface elevations. These results can be exported to GIS, overlaid onto the terrain model, and used to delineate inundation areas for the study reach. The updated delineation for the base (100-year) flood can be used, along with depth and velocity data to map new flood hazard zones (i.e., DFF floodway and flood fringe).

Modeling should be conducted in accordance with FEMA standards for flood hazard mapping. The analyses should then be used to apply for a Letter of Map Revision (LOMR), which is required to change the effective FIRM maps used by FEMA to determine flood insurance rates. A LOMR application for the Nisqually River will require a cooperative effort between the floodplain coordinators at Pierce County and Thurston County.

Complete Channel Migration Zone (CMZ) Study

Pierce County Code requires that the Nisqually River channel migration zones (CMZ) be regulated as floodways. A CMZ study for the upper Nisqually River was completed, but a study of the lower Nisqually River has not been completed. A CMZ study, similar to the one conducted on the upper Nisqually River, should be conducted on the lower Nisqually River from the Nisqually Estuary to La Grande Dam. Based on the study completed for the Upper Nisqually the study should include:

- Data will be collected and reviewed including historical aerial photographs.
- GIS mapping tools will be used to overlay and analyze spatial data.
- A geomorphic evaluation will be conducted including site verification.
- Geologic and hydrologic analyses will be completed.
- Severe and moderate channel migration zones will be delineated.

Survey Structures – Elevation Certificates

Elevation data should be collected for all of the structures identified to be within the updated flood hazard area. These data will not only be useful for identifying at-risk structures for flood damage assessments, but also fulfill FEMA requirements for elevation certificates. Surveyors would need to obtain right-of-entry for all properties to be assessed.

FEMA has developed an administrative tool referred to as an elevation certificate, which is a document containing information about a structure that can be used by FEMA to make flood insurance rate determinations. These certificates are required for all new development within a designated SFHA, and maintaining a file of these certificates is a component of the Community Rating System (CRS). Data required on an elevation certificate include:

- Top of bottom floor

- Top of next higher floor
- Lowest adjacent grade (LAG)
- Highest Adjacent Grade (HAG)
- Elevation of a basement or crawl space
- Number and area of openings below the base flood elevation

It is also important to determine whether a structure is pre-FIRM or post-FIRM. This can be confirmed by comparing the date the structure was built with the date the first effective FIRM was published for the community.

Elevation certificates already on file at the County should be collected and reviewed. Following the review, new elevation certificates should be completed for each structure within the flood hazard zone that does not have an elevation certificate, or if the existing certificate is deficient.

Project Funding

Project funding should be considered early in the planning process to ensure that appropriate steps are followed to qualify for assistance, and because funding constraints may influence project formulation. The following are some funding options that should be considered:

- **FEMA – Hazard Mitigation Grant Program (HMGP):** HMGP funds are available following a Presidentially-declared disaster. Funds are made available to local governments to implement long-term hazard mitigation measures. These funds will only be made available immediately following a Presidentially-declared disaster.
- **FEMA – Flood Mitigation Assistance (FMA) Program:** The FMA Program provides funds to communities for measures that reduce or eliminate long-term flood risk for damage to buildings, manufactures homes, and other structures insured under the National Flood Insurance Program (NFIP). Grants are provided for mitigation planning and projects were the objective is to reduce claims under the NFIP.
- **FEMA – Pre-Disaster Mitigation (PDM) Program:** The PDM Program assists local governments with disaster mitigation activities that compliment a comprehensive mitigation program. The goal is to raise awareness and reduce the risk of losses before disaster strikes. Communities must have FEMA-approved mitigation plans in order to be eligible.
- **FEMA – Repetitive Flood Claims (RFC) Grant Program:** The RFC Grant Program is designed to reduce or eliminate long-term risk of flood damage to structures insured under the NFIP that have had one or more claims. RFC funds may only be used to mitigate structures in communities that cannot meet the requirements of the FMA Program.

- **FEMA – Severe Repetitive Loss (SRL) Pilot Program:** The SRL Pilot Program provides funds to assist communities in reducing or eliminating long-term flood risk to severe repetitive loss properties. A severe repetitive loss property is defined as a residential property currently insured under the NFIP, and has incurred flood losses that resulted in either:

  1. Four or more flood insurance claims that exceeded $5,000 with at least two or more of these payments occurring within a 10-year period, or

  2. Two or more flood insurance claims that have cumulatively exceeded the value of the property.

- **State of Washington – Flood Control Account Assistance Program (FCAAP):** The Department of Ecology (Ecology) provides assistance through matching grants for the preparation of comprehensive flood management plans, for flood control maintenance projects and studies, as well as for emergency flood-related projects.
- **United States Army Corps of Engineers (USACE) – Section 205:** Section 205 of the 1948 Flood Control Act provides authority to the Corps of Engineers to plan and construct small flood damage reduction projects that have not been specifically authorized by congress. A project must show through detailed investigation that it is technically feasible, environmentally acceptable, and economically justifiable. Projects must be complete, and cannot be components of larger projects. The maximum federal expenditure per project is $7 million, which includes both planning and construction costs.
- **Congressional Lobbying Efforts to obtain Federal and/or State Funding.**
- **Contributions from the private sector.**

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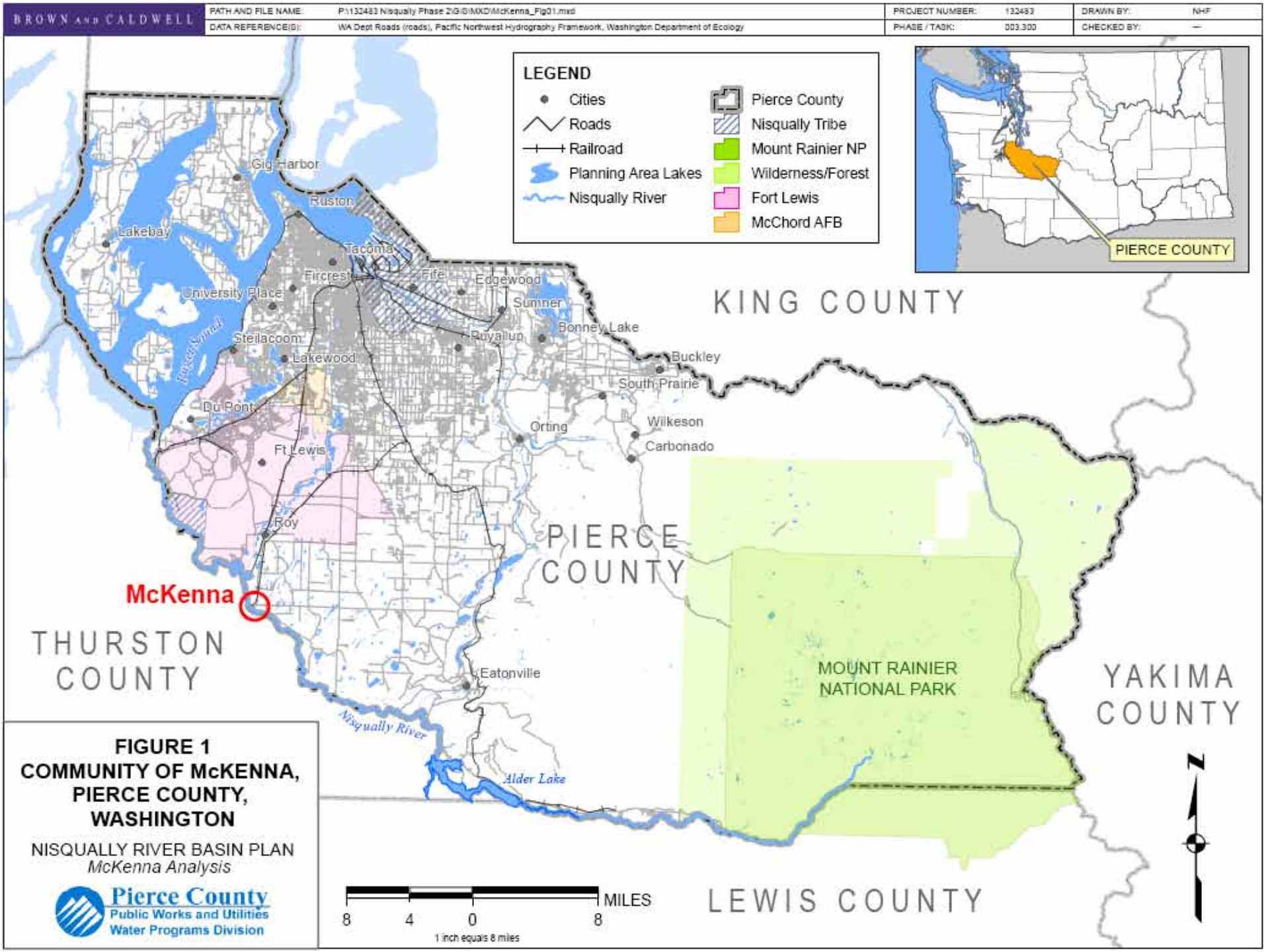
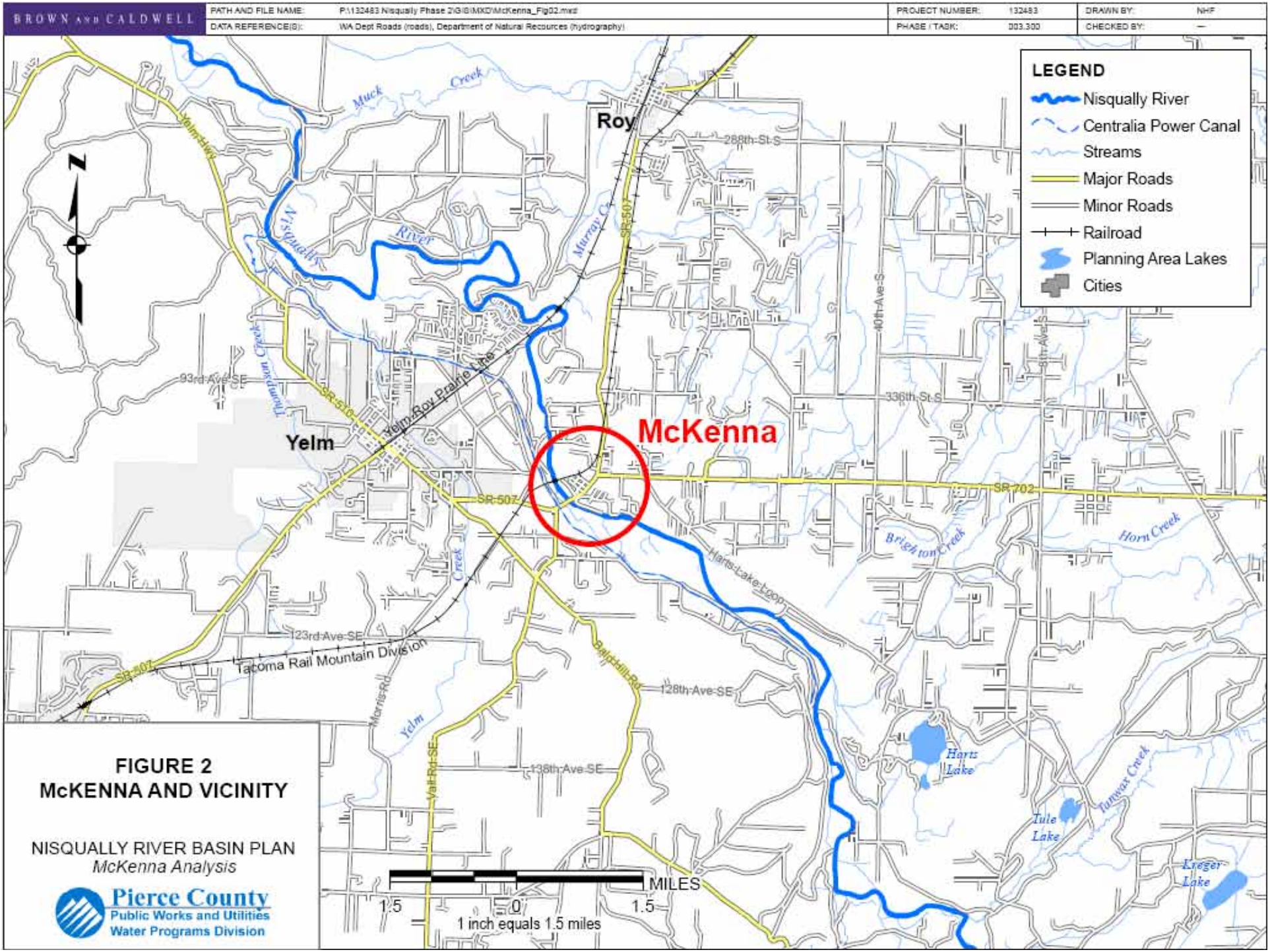


FIGURE 1
COMMUNITY OF McKENNA, PIERCE COUNTY, WASHINGTON

NISQUALLY RIVER BASIN PLAN
McKenna Analysis

Pierce County
Public Works and Utilities
Water Programs Division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PROJECT NUMBER: 132483
PHASE / TASK: 003.300
DRAWN BY: NHF
CHECKED BY: —
LEGEND
Nisqually River
Centralia Power Canal
Streams
Major Roads
Minor Roads
Railroad
Planning Area Lakes
Cities
McKenna
Yelm
Roy
Muck Creek
Yelm Hwy
Murray Cr
SR-507
288th St S
40th Ave S
84th Ave S
336th St S
93rd Ave SE
SR-510
Yelm-Roy Prairie Line
SR-702
Brighton Creek
Horn Creek
Harts Lake Loop
123rd Ave SE
Tacoma Rail Mountain Division
Morris Rd
Yelm Creek
Ball Hill Rd
128th Ave SE
138th Ave SE
Vail Rd SE
Harts Lake
Tule Lake
Tanwax Creek
Kreger Lake
1.5 0 1.5 MILES
1 inch equals 1.5 miles
FIGURE 2
McKENNA AND VICINITY
NISQUALLY RIVER BASIN PLAN
McKenna Analysis
Pierce County
Public Works and Utilities
Water Programs Division

BROWN AND CALDWELL	PATH AND FILE NAME:	P:\132483 Nisqually Phase 2\GIS\MXD\McKenna_Fig03.mxd	PROJECT NUMBER:	132483	DRAWN BY:	NHF
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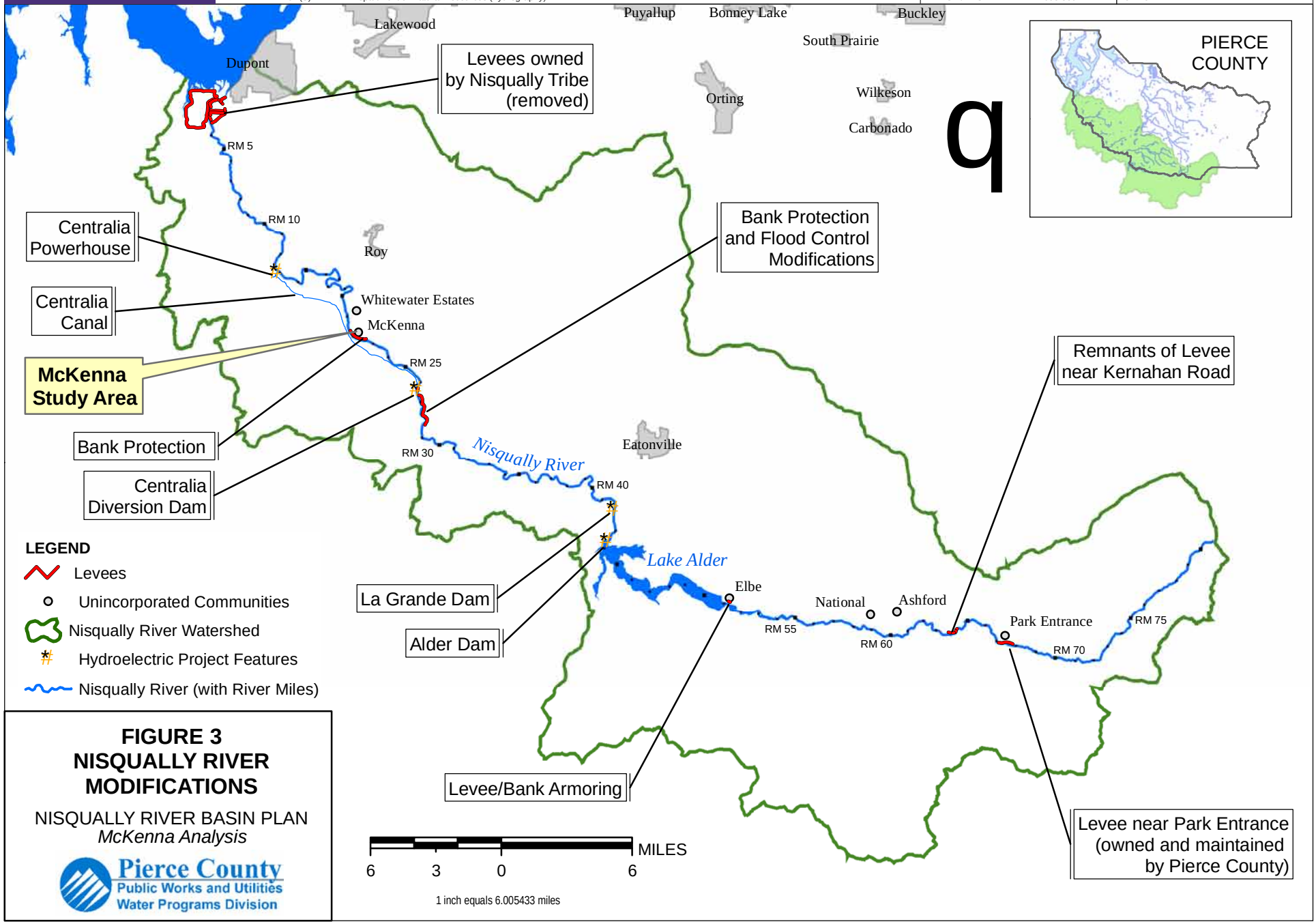

FIGURE 3
NISQUALLY RIVER MODIFICATIONS

NISQUALLY RIVER BASIN PLAN
McKenna Analysis

Pierce County
Public Works and Utilities
Water Programs Division

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	DATA REFERENCE(S):	U.S. Geological Survey (gages), Pacific Northwest Hydrography Framework	PHASE / TASK:	003.300	CHECKED BY:	—

Site Number	Station Name	Status	Start	End	Years
12081500	MCALLISTER SPRINGS NEAR OLYMPIA, WA	Inactive	1951	1964	11
12090200	MUCK CREEK AT ROY, WA	Inactive	1956	1971	15
12089500	NISQUALLY RIVER AT MCKENNA, WA	Active	1947	2007	47
12089208	CENTRALIA POWER CANAL NEAR MCKENNA, WA	Active	1979	2007	25
12089000	TANWAX CREEK NEAR MCKENNA, WA	Inactive	1944	1950	6
12088500	NISQUALLY RIVER NEAR MCKENNA, WA	Inactive	1941	1963	22
12088400	NISQUALLY RIVER AB POWELL CREEK NEAR MCKENNA, WA	Inactive	1969	1979	11
12088000	OHOP CREEK NEAR EATONVILLE, WA	Active	1927	2007	46
12087000	MASHEL RIVER NEAR LA GRANDE, WA	Active	1940	2007	29
12085500	LA GRANDE RESERVOIR AT LA GRANDE, WA	Active	1973	2007	34
12086500	NISQUALLY RIVER AT LA GRANDE, WA	Active	1906	2007	77
12085000	ALDER RESERVOIR AT ALDER, WA	Active	1973	2007	34
12084500	LITTLE NISQUALLY RIVER NEAR ALDER, WA	Inactive	1920	1943	23
12084000	NISQUALLY RIVER NEAR ALDER, WA	Inactive	1931	1944	13
12083500	EAST CREEK NEAR ELBE, WA	Inactive	1916	1950	5
12083000	MINERAL CREEK NEAR MINERAL, WA	Active	1942	2007	61
12082500	NISQUALLY RIVER NEAR NATIONAL, WA	Active	1942	2007	61

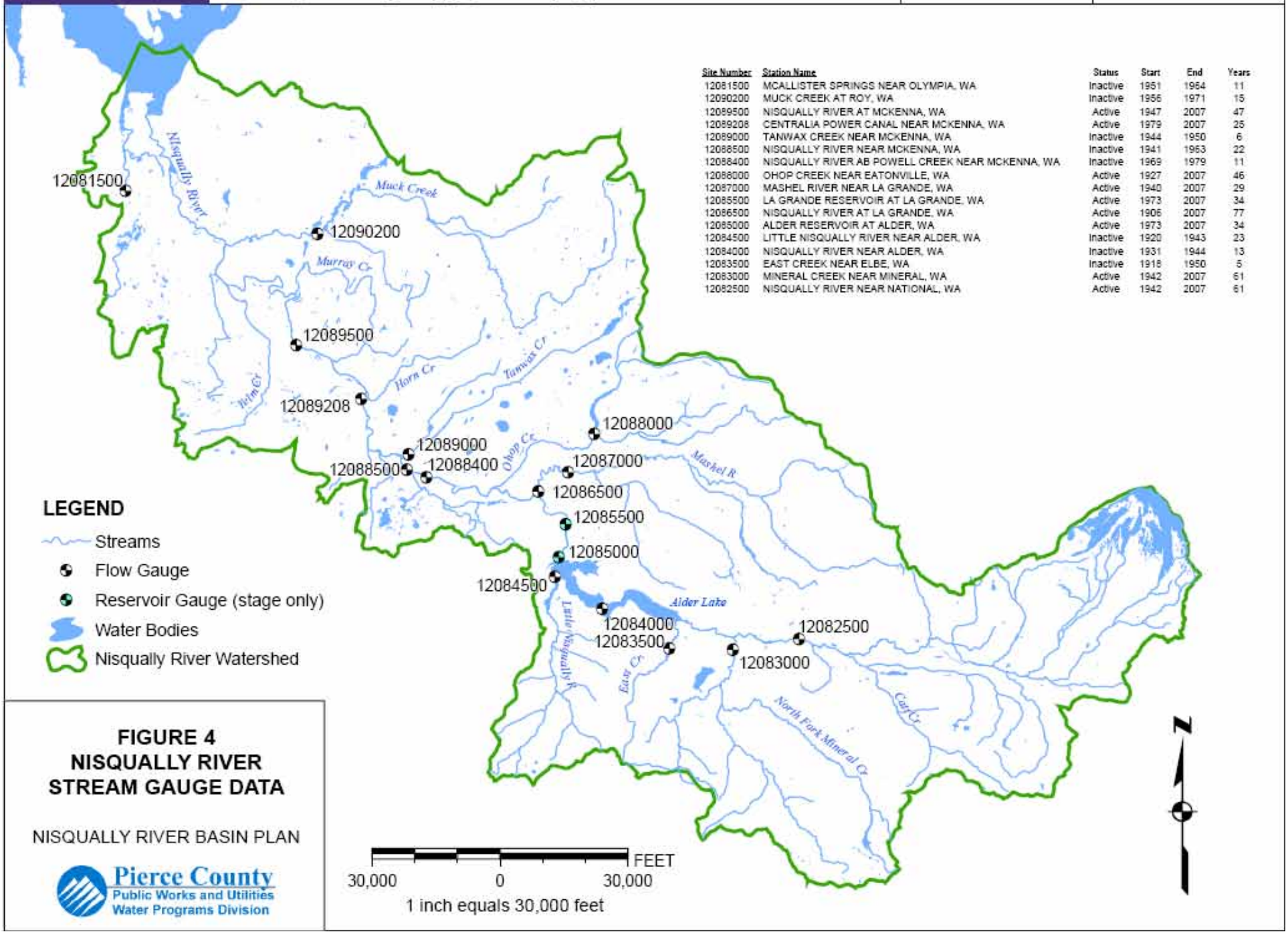


FIGURE 4
NISQUALLY RIVER
STREAM GAUGE DATA

NISQUALLY RIVER BASIN PLAN

Pierce County
Public Works and Utilities
Water Programs Division

BROWN AND CALDWELL	PATH AND FILE NAME:	P:\132483 Nisqually Phase 2\GIS\MXD\McKenna_Fig05.mxd	PROJECT NUMBER:	132483	DRAWN BY:	NHF
	DATA REFERENCE(S):	United States Geological Survey	PHASE / TASK:	003.300	CHECKED BY:	—

Map and Schematic obtained from USGS:
http://wa.water.usgs.gov/data/realtime/adr/interactive/maps/NisquallySC_basin.pdf
http://wa.water.usgs.gov/data/realtime/adr/interactive/schematics/Nisqually.pdf

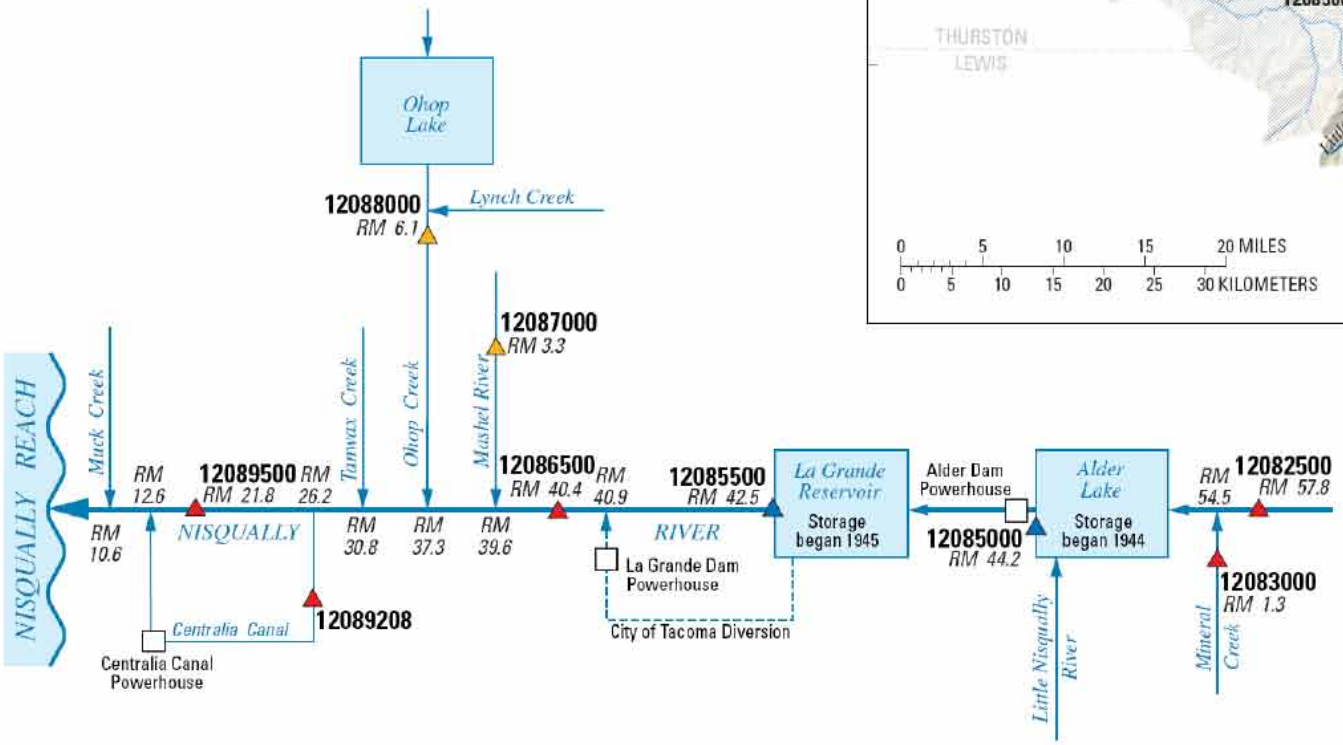


FIGURE 5
USGS SCHEMATIC AND MAP
ACTIVE NISQUALLY GAUGES

NISQUALLY RIVER BASIN PLAN

Pierce County
Public Works and Utilities
Water Programs Division

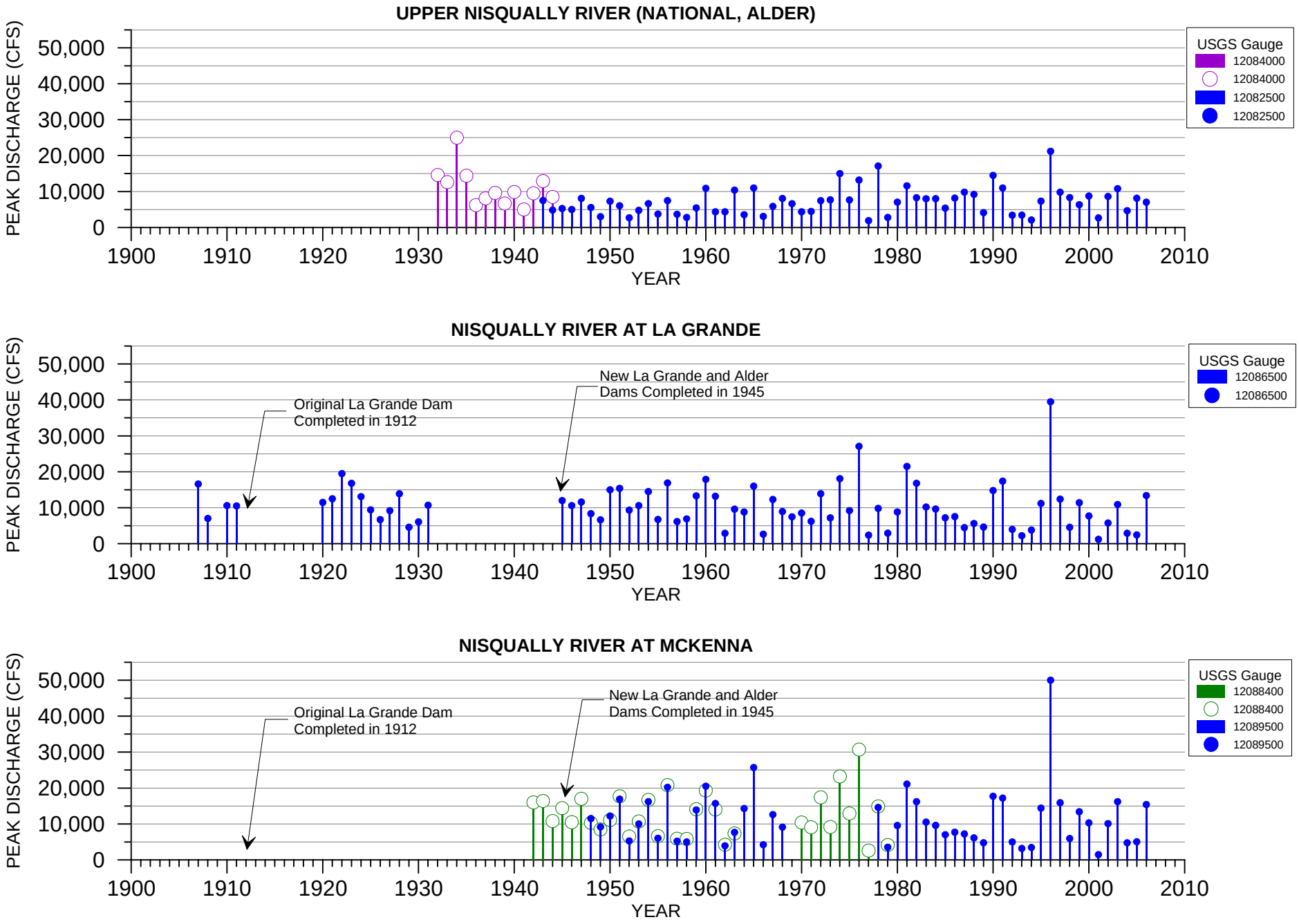


FIGURE 6. Annual Peak Discharges Recorded at the Nisqually River Gauges

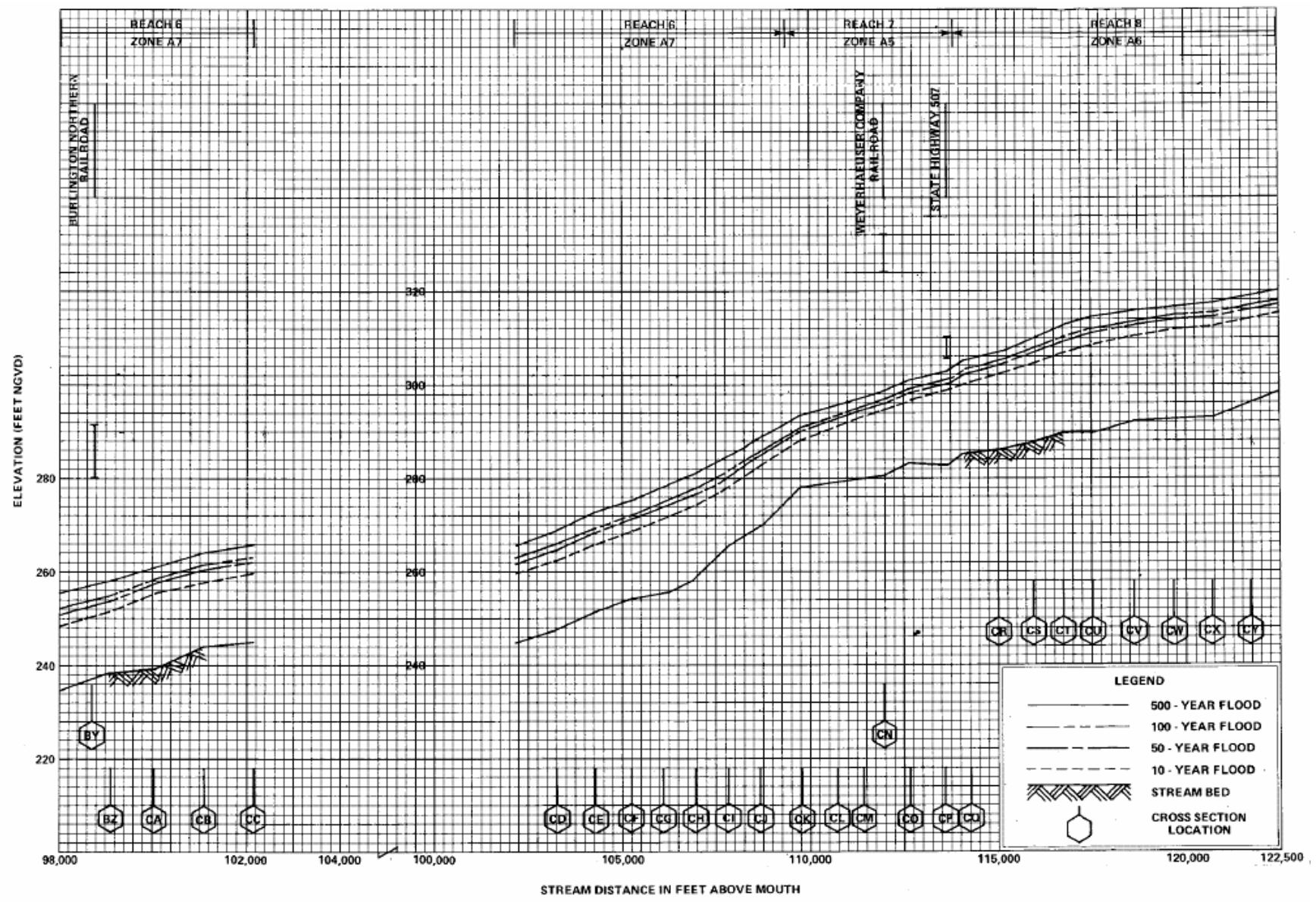


Figure 7. Flood Profiles for the Nisqually River Near McKenna (FEMA, 1987)

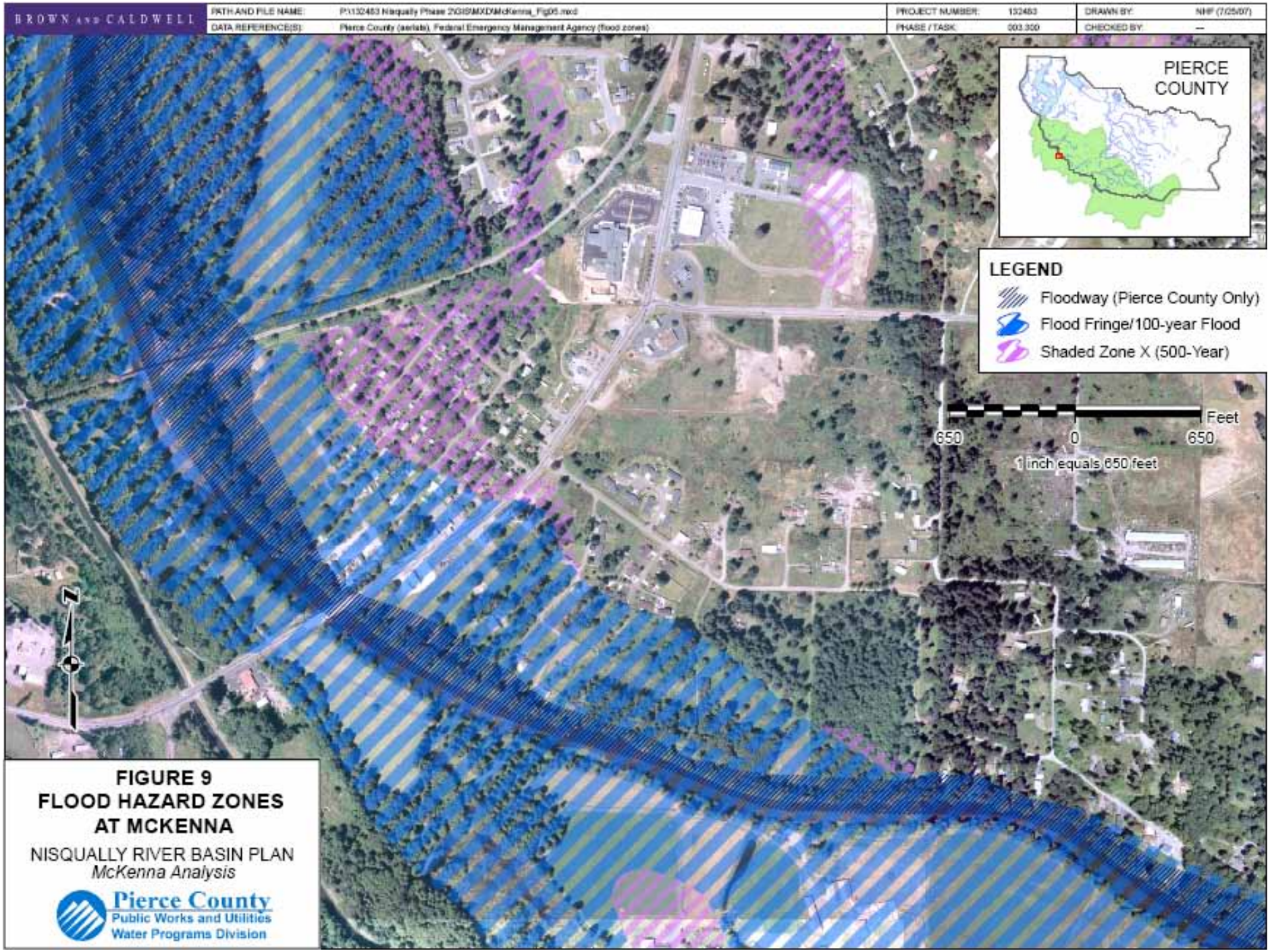


FIGURE 9
FLOOD HAZARD ZONES AT MCKENNA

NISQUALLY RIVER BASIN PLAN
McKenna Analysis

Pierce County
Public Works and Utilities
Water Programs Division

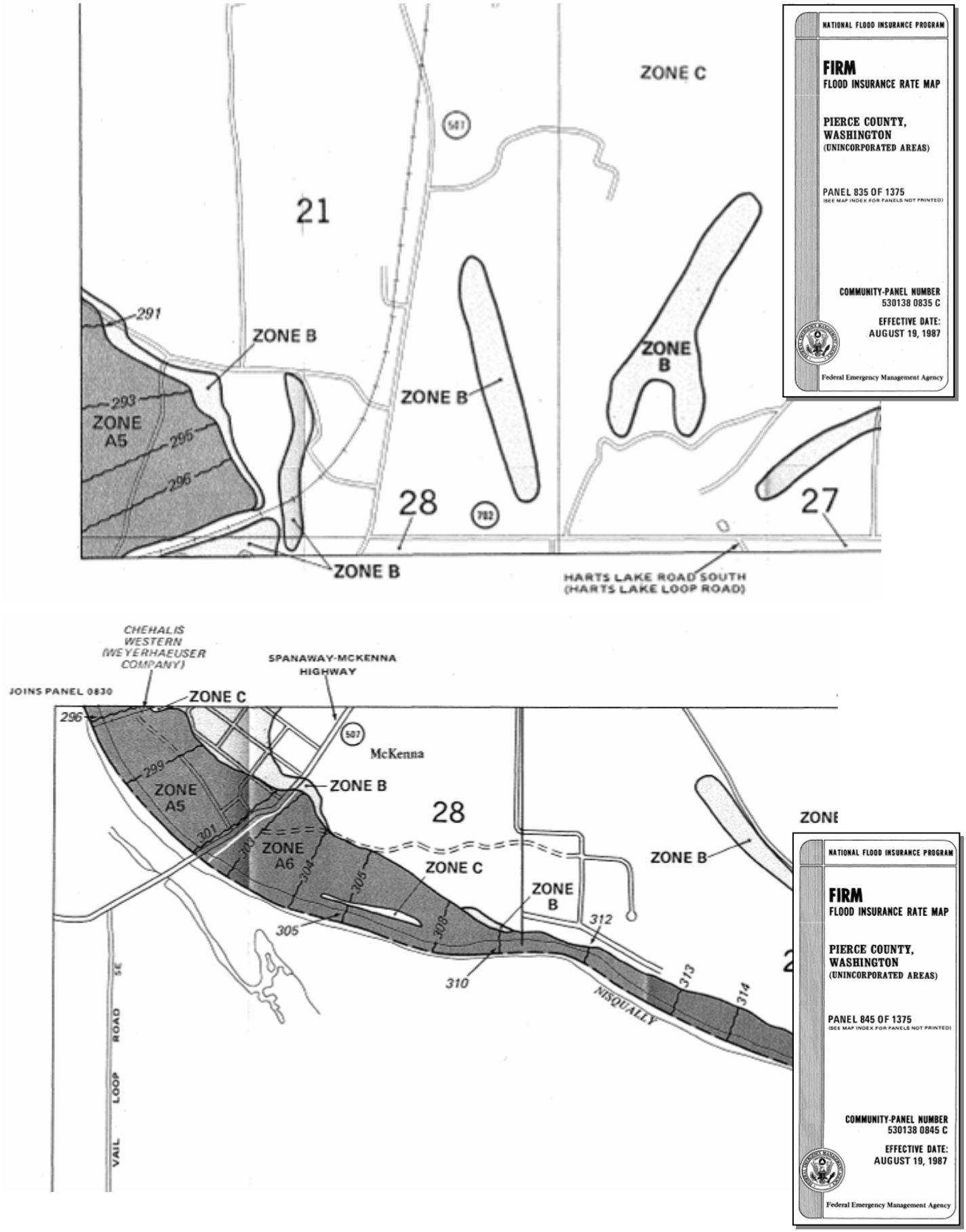


Figure 8. Relevant Sections of the FEMA FIRM Panels at McKenna

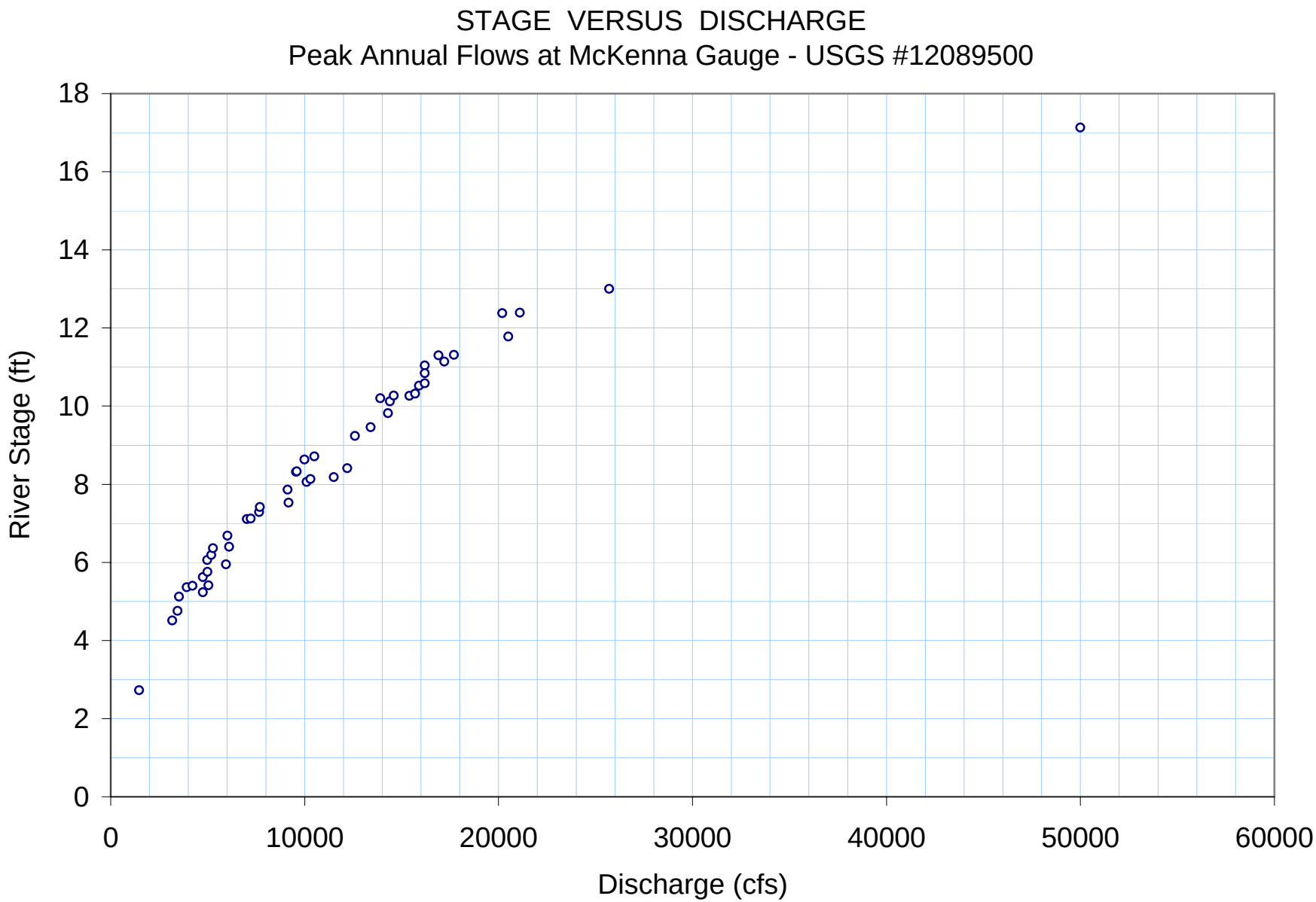


Figure 10. River Stages versus Peak Discharges for the Peak Annual Flow Data at McKenna Gauge No. 12089500

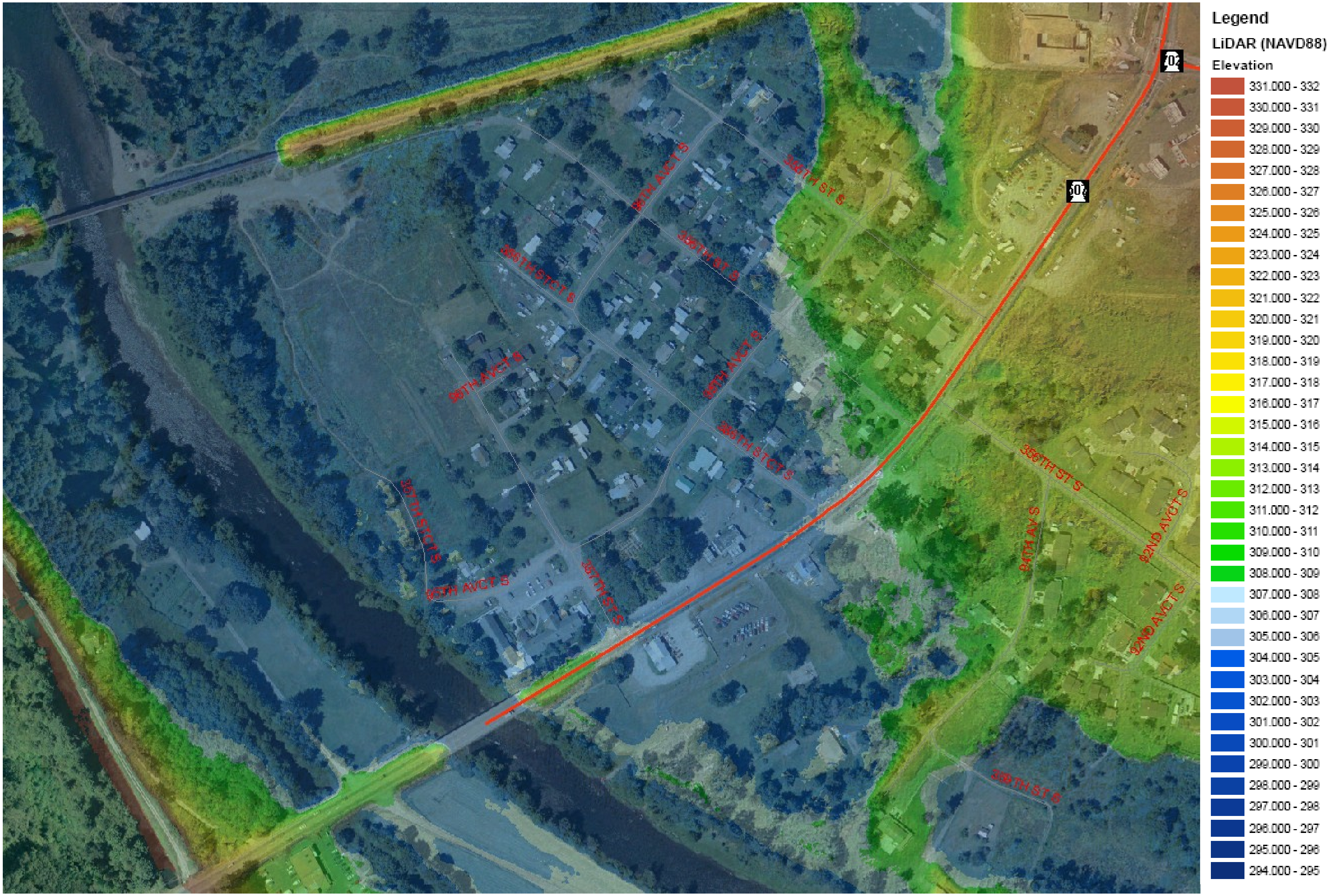
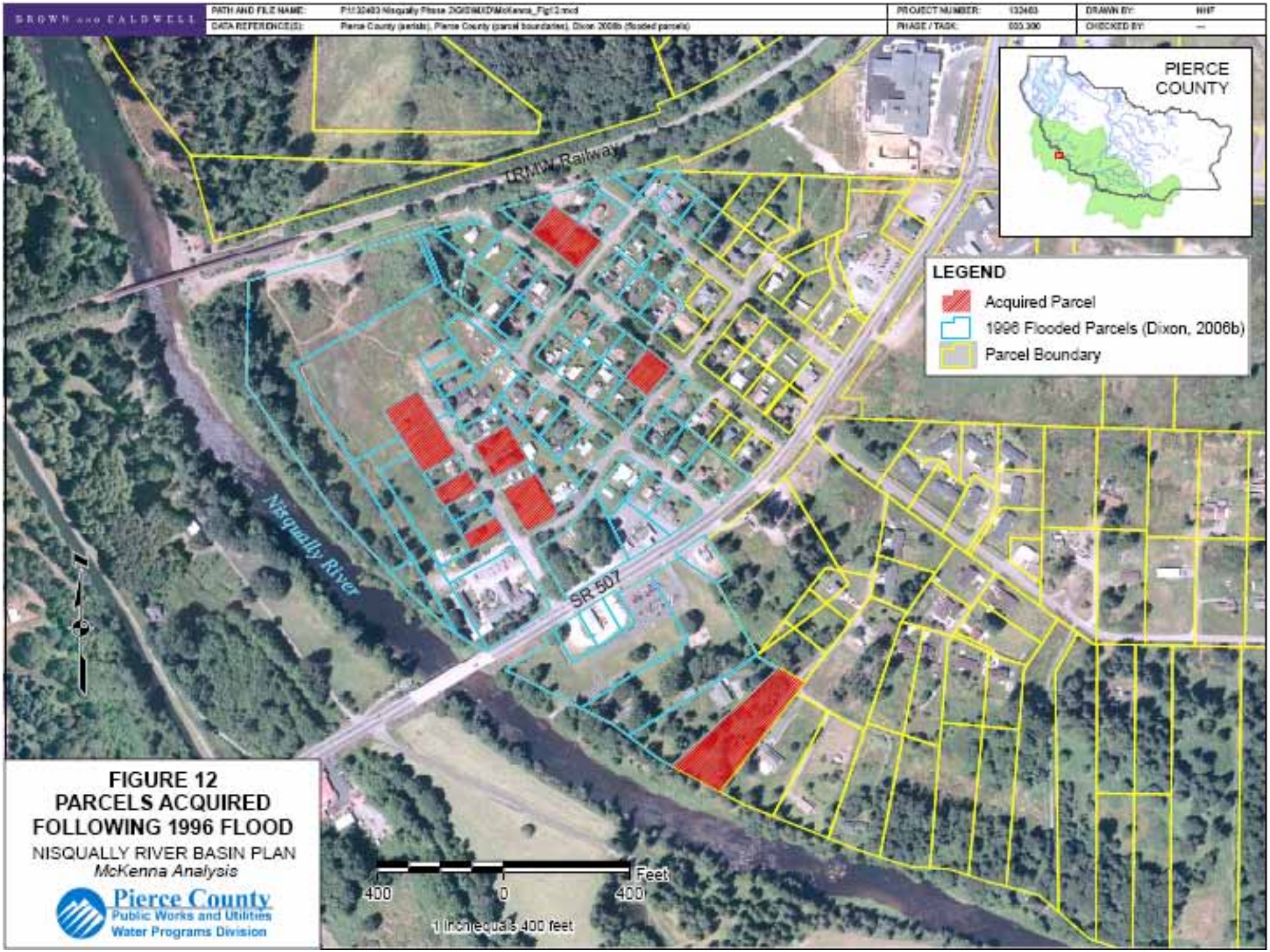


Figure 11. Inundated Area (shaded blue) from Flood in February 1996 (Dixon, 2006a)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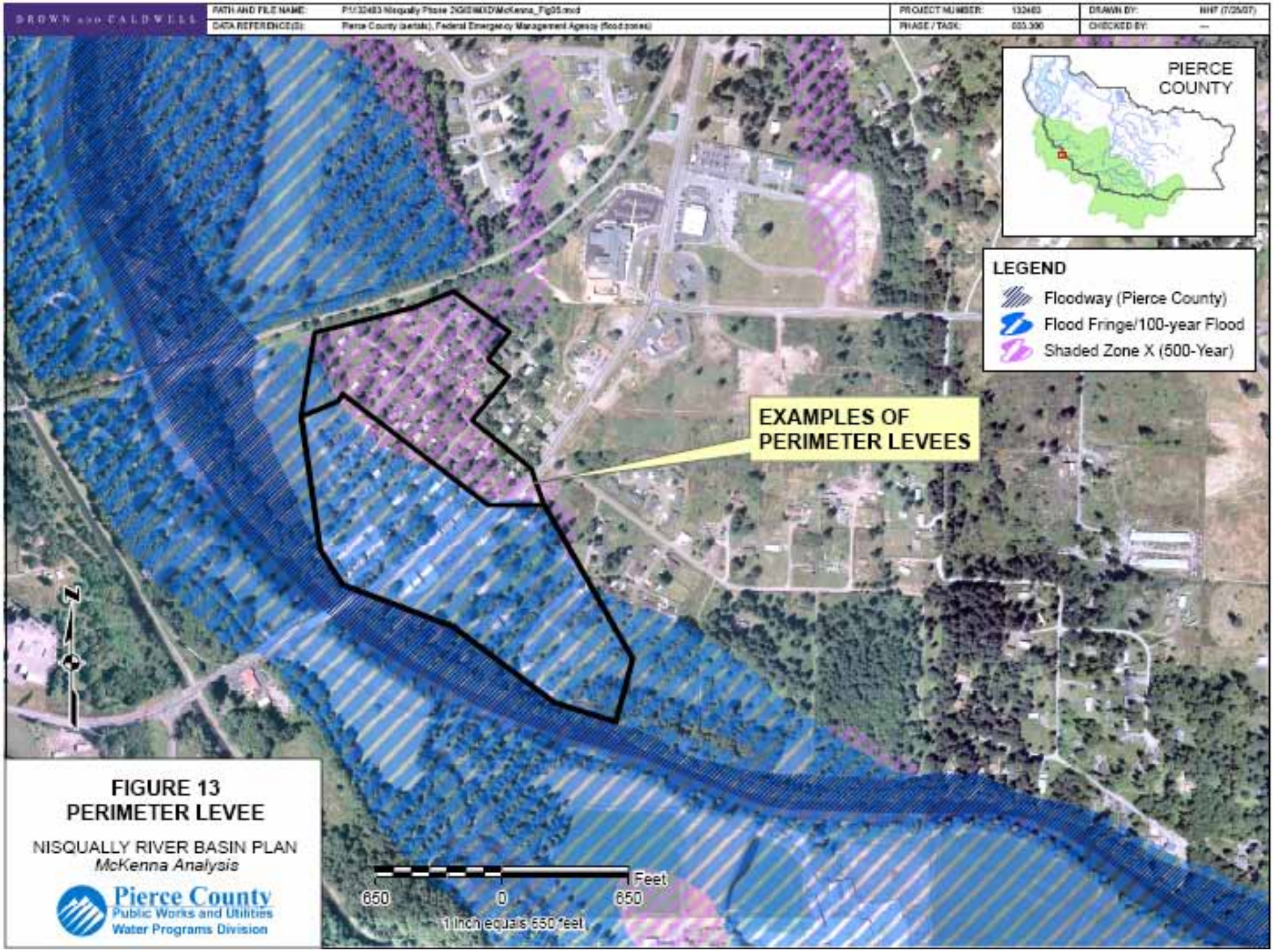
PROJECT NUMBER: 132483
PHASE / TASK: 003.300
DRAWN BY: MHF
CHECKED BY: —
PIERCE COUNTY
LEGEND
Acquired Parcel
1996 Flooded Parcels (Dixon, 2006b)
Parcel Boundary
DRMW Railway
Nisqually River
SR 507
400
0
400
Feet
1 Inch equals 400 feet
FIGURE 12
PARCELS ACQUIRED
FOLLOWING 1996 FLOOD
NISQUALLY RIVER BASIN PLAN
McKenna Analysis
Pierce County
Public Works and Utilities
Water Programs Division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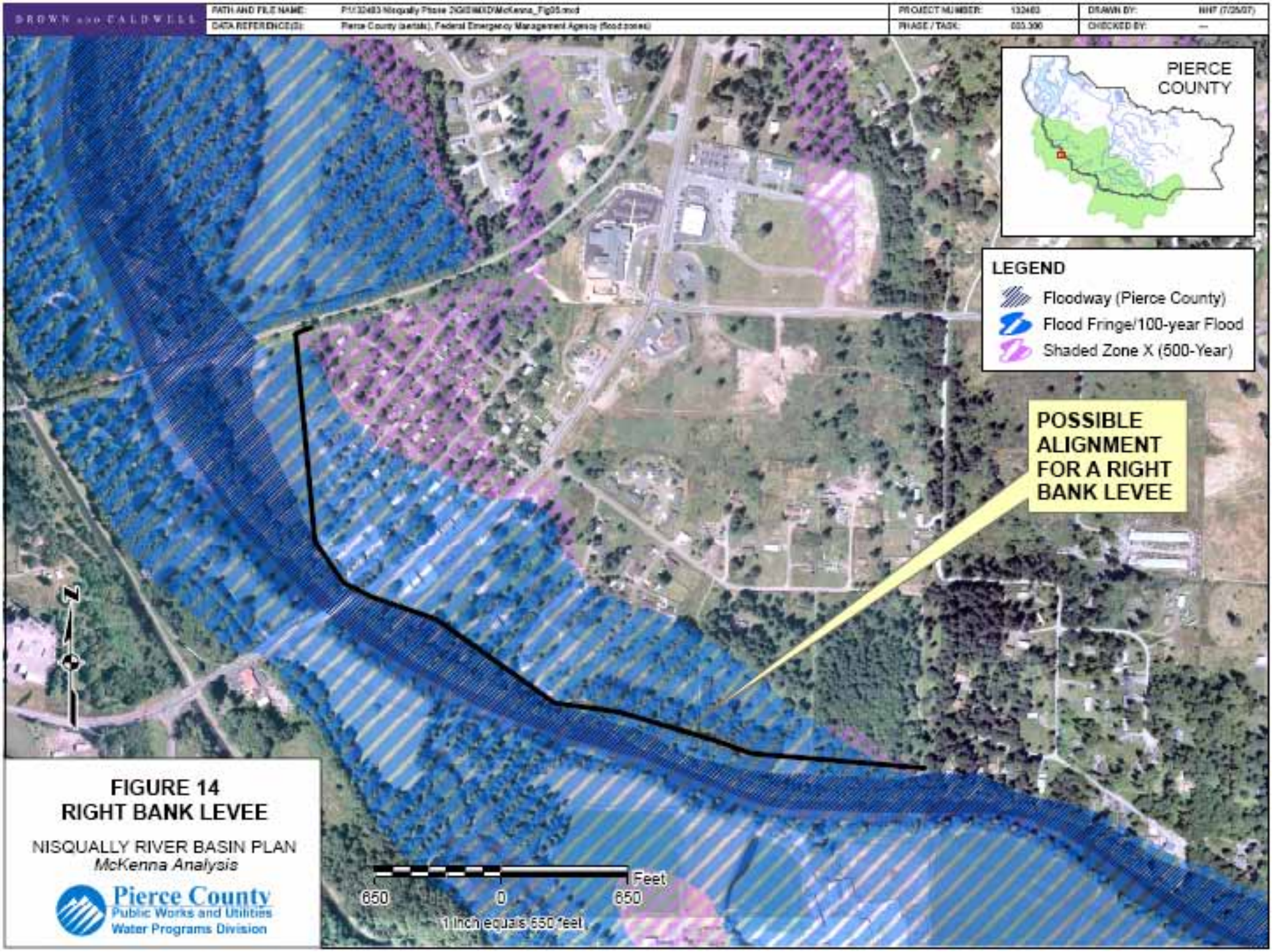
DATA REFERENCE(S): Pierce County (aerials), Federal Emergency Management Agency (flood zones)
PROJECT NUMBER: 132483
PHASE / TASK: 003.300
DRAWN BY: NHF (7/25/07)
CHECKED BY: —
PIERCE COUNTY
LEGEND
Floodway (Pierce County)
Flood Fringe/100-year Flood
Shaded Zone X (500-Year)
EXAMPLES OF PERIMETER LEVEES
N
650
0
650
Feet
1 inch equals 650 feet
FIGURE 13
PERIMETER LEVEE
NISQUALLY RIVER BASIN PLAN
McKenna Analysis
Pierce County
Public Works and Utilities
Water Programs Division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DATA REFERENCE(S): Pierce County (aerials), Federal Emergency Management Agency (flood zones)
PROJECT NUMBER: 132483
PHASE / TASK: 003.300
DRAWN BY: MHF (7/25/07)
CHECKED BY: —
PIERCE COUNTY
LEGEND
Floodway (Pierce County)
Flood Fringe/100-year Flood
Shaded Zone X (500-Year)
POSSIBLE ALIGNMENT FOR A RIGHT BANK LEVEE
N
650
0
650
Feet
1 inch equals 650 feet
FIGURE 14
RIGHT BANK LEVEE
NISQUALLY RIVER BASIN PLAN
McKenna Analysis
Pierce County
Public Works and Utilities
Water Programs Division